Advanced Nuclear Science and Technology Techniques (ANSTT3) Workshop

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J Block

Book of Abstracts

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Metrology and Applications / **1**

The Significance of a Protocol in X-ray Radiography: Influential Parameters

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Background Information and Aims: X-ray imaging is one of the classical human health diagnostic procedures. The aim of this work was to explore and analyze the X-ray exposure parameters and their significance in a given protocol in relation to image quality.
Materials and Methods: Exposures were delivered on meaty cow ribs, which served as a human equivalent phantom with tissue heterogeneities. Six different protocols corresponding to the foot, wrist, ankle, forearm, chest, and hand were used in exposing the phantom with a Shimadzu RAD speed MC unit. The resultant images were analyzed with Image J software for relative intensities so as to index image quality per protocol.
Results and Discussions: There were variations in the relative intensities read at selected image pixels protocol by protocol. This showed that the relative intensities can be used to make predictions of image quality and associated dose.
Conclusions: It is crucial to use the appropriate protocol for any given X-ray imaging procedure to minimize the dose delivered to tissue without compromising image quality. Relative intensity and thus optical density can be used as a measure of image quality and radiation dose by protocol.

Neutron Physics and Applications / **2**

Measurements of concrete composition via fast neutron transmission spectrometry

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Within all nuclear installations concrete is a key material both for structural integrity and for the shielding of radiation. Concrete is typically a mixture of cement, sand, large aggregate and water, although various additives may also be introduced. Developing methods to independently verify the composition of shielding materials, such as concrete, is of high priority for the regulation of existing and future nuclear installations. Of particular importance to the neutron shielding properties of concrete is the water content, which has further significance as nuclear installations age.

We report on the development of radiation-based methods to non-destructively measure the composition of concrete and other materials. Measurements of the energy spectra of neutrons transmitted through well-characterised samples were made at the n-lab (Department of Physics, University of Cape Town) with beams of 14 MeV neutrons from a D-T sealed tube neutron generator and neutrons produced from an AmBe radioisotopic source. Modern methods of spectrum unfolding allow energy spectra to be determined without the need for ns-pulsed neutron beams. The measurements were supported by radiation transport calculations using FLUKA. We present analyses of measured neutron energy spectra, and FLUKA calculations, which offer new opportunities to non-destructively determine the composition of concrete samples of unknown origin.

Metrology and Applications / 3

Radioisotope tracer techniques for the study of multiphase flows

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At iThemba LABS Positron Emission Particle Tracking (PEPT) is used to study dynamic physical processes and multiphase flow phenomena. Studies of these often turbulent systems contribute to understanding of fundamental flow behaviour and are of increasing interest in the current climate of reducing industrial wastes, improving process efficiencies, and developing design lead approaches to industrial systems. PEPT results are critical for the evaluation of computational models of such phenomena.

In the spirit of the previous ANSTT meetings we will update on recent research produced by the PEPT Cape Town laboratory, including aspects of our four key themes: instrumentation & detector development, radioisotope tracer techniques (physical and chemical), data acquisition & processing, and the applications of such measurements. Noting that such Advanced Nuclear Science, Technology, Techniques, and ultimately their applications, are large scale multidisciplinary endeavours there will be a strong focus on our role in personnel development and training involving researchers from a diverse range of backgrounds. We will offer thoughts into collaboration building around these techniques, particularly in the application phase space.

Environmental Measurements / 5

Assessment of Radiological hazards for Latrite Mining Field in Ilorin South LGA, North-central Nigeria

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Assessment of activity concentrations of 40K, 238U, 232Th and gamma dose rate (DR) was carried out over a latrite mining field using a well calibrated Super-Spec (RS-125) gamma spectrometer, along Ajese-Ipko road, Ilorin-south, Kwara state, Nigeria. The results of the radioactivity measurements were used to assess the radiological hazards associated with the latrite mining field and it's suitability as building material. Fifty (50) measurements of the activity concentration of the radionuclides were obtained at about 1 meter above the topsoil to cover a large area. For each of these 50 sample points, measurements were taken four (4) times for better accuracy. The mean activity concentrations of 238U and 232Th are higher than their corresponding global average of 32.00 Bqkg-1 and 30.00 Bqkg-1 respectively provided by UNSCEAR. This is a cause for worry as significant enhancement in the concentration of 238U and 232Th will increase the level of the background radiation and possibly render the soil unfit for use in building and construction purposes. The results of the radiological impact parameters (RIP) such as the mean values of the indoor radiation dose rate (Din). indoor Annual Effective Dose (EADindoor) and Annual Gonadal Equivalent Dose (AGED) are above the recommended limits provided by UNSCEAR. Since other hazard parameters are close or could possibly be approximated to the permissible limit, this implies that the lateritic soil from this mine field

may not be too suitable for building and construction purposes (either as raw material or finished product).

The MeASURe experience / 6

Development of a digital data acquisition system for neutron metrology

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Fast neutron fields are found in a wide variety of contexts, for example at accelerator and medical radiation facilities, around nuclear power plants, in airplanes in flight and space stations. These fields often vary widely with respect to both energy and intensity which complicates measurements of energy dependent fluence. Bonner sphere systems remain widely in use, although systems based on scintillator detectors offer distinct advantages including improved energy resolution on the fast neutron energy range (above 1 MeV). Since scintillators are typically sensitive to all types of radiation, including gamma rays, it is necessary to select neutron-only events, and pulse shape discrimination capabilities of selected scintillators is typically used for this purpose. Digital pulse processing electronics offer several distinct advantages over analogue systems, including being more cost effective and compact, but most importantly the flexibility of analyzing raw pulses in list mode.

Within the neutron metrology and spectrometry community digital pulse processing systems are being developed for a variety of purposes. New digital data acquisition systems need to be benchmarked against the current metrology standards, typically based on analogue systems. We present a comparison between the IRSN fast neutron metrology analogue acquisition system to an off-the-shelf CAEN desktop digitizer. Measurements were made using a BC-501A scintillator detector at IRSN AMANDE accelerator based facility. Uncertainty budgets for measurements of neutron energy dependent fluence distributions are compared for the analogue and digital acquisition systems. The broader aim of this project is to further the development of a digital data acquisition system for fast neutron metrology using advanced scintillator technology for use in neutron fields where time-of-flight may or may not be available.

Metrology and Applications / 7

F-18 activity mesurements at NMISA

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F-18 is an important radionuclide in PET imaging and is produced at iThemba LABS. Therefore, iThemba LABS and other producers and users of F-18 require traceability from a metrology institute. At NMISA the absolute activity of F-18 was determined through a primary measurement using 4πβ-γ

liquid scintillation coincidence counting. Conventional beta-efficiency extrapolation was employed. Subsequently, a factor for the NMISA ionization chamber was determined and used during a SIRTI comparison. A non-extrapolation method based on a detection efficiency analysis was also employed to analyse the data, using an adaptation of the double-phototube coincidence efficiency for a threshold above the second monopeak. Results and uncertainty budgets for the two methods are presented and discussed. Dissemination of F-18 traceability to iThemba LABS is also presented.

Environmental Measurements / **8**

The investigation of natural radionuclides as tracers for monitoring sediment processes

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In situ and sampling measurements of naturally occurring radionuclides were investigated in terrestrial sediment in various environments. These environments include beaches, wetlands, river basins, and deserts that are within Southern Africa. The distribution patterns of the natural radionuclides were extracted and characteristics were compared and investigated. These characteristics were used to develop a method that can radio fingerprint types of sediment. The fingerprinting can then be used as a tracer to track sediment movement in aquatic systems when artificial disturbances, like dredging, occur.

Environmental Measurements / **9**

The VIDEO project

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The aim of the VIDEO project is the development of a device enabling the detection and location of gamma radiation from hidden sources. The intended application of the device is finding dirty bombs, preventing terrorist attacks with radioactive material. Thus ultimate detection sensitivity and capability of tracking moving gamma sources is required. The project is running since 2011 at GSI in close contact with German security forces. It relies on gamma detection methods developed at GSI for the detection of rare gamma quanta in nuclear reactions investigated in basic research. These methods were adopted to the needs of VIDEO. A hand-held device, VIDEO-2 has been built to demonstrate the basic functionality. The detector unit includes six scintillator detectors (read-out by SiPM arrays) enabling full 2D and limited 3D direction determination of a single source. For optimal performance in terms of isotope identification and rate capability, CeBr3(Tl) crystals with their good energy resolution and fast signal are chosen. A detection sensitivity of >2500 cts/s at 1 µSv/h and a direction sensitivity of 2 degree has been reached. The detector is scalable to further increase sensitivity, for instance for vehicle based systems for remote sensing of radioactive sources over very large distances. Other applications are possible, notably remote monitoring systems for environmental surveillance and nuclear installation control.

Metrology and Applications / **10**

Design and construction of a gamma-ray spectrometer with water shielding for low-level natural occurring radioactive material measurement

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Gamma-ray spectrometer with a single HPGe or NaI:Tl detector shielded with lead is often used to measure the activity concentration of radionuclides in soil samples. A passive water shield to reduce background radiation reaching the detectors was designed using GEANT4 Monte Carlo simulations and then constructed. IAEA-375 soil and beach sand each placed in Marinelli beaker were measured for 48 hours using two LaBr3:Ce detectors placed inside the constructed water shield. The samples were also measured for 24 hours using a NaI:Tl detector inside the constructed water shield and HPGe shielded with lead and copper to compare and validate the results from measurements with the LaBr3:Ce detectors. Both the simulated and measured results show that the water shield attenuates the 2614.5 keV gamma rays by over 90 % and energies lower than the 2614.5 keV by far above 90 %. The activity concentration of K-40 radionuclide in IAEA-375 soil and beach sand measured using the LaBr3:Ce detectors was below the minimum detectable activity (MDA) due to the internal activity of the detector. The measured activity concentrations of U-238 and Th-232 series and K-40 radionuclides in IAEA-375 soil were comparable with certified values to within measurement uncertainties. The activity concentrations of U-238 and Th-232 series radionuclides in beach sand were determined using all the measurement geometries and consistent to within 1σ to 2σ level.

Neutron Physics and Applications / **12**

Magnetized dense neutron matter

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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 are 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.

Neutron stars are the densest stable states of matter that can currently be directly observed. Some neutron stars ("pulsars") emit strongly in the radio part of the electromagnetic spectrum. Observation of this radiation is one of the major observational targets of what will the world's largest radio telescope, the Square Kilometre Array.

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 matter, its equation of state, and how the equation of state is applied to study neutron stars.

The MeASURe experience / 13

The central role of metrology in applied nuclear physics research

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The art and act of measurement lie at the very heart of the enterprise of Science. Measurement mediates between the complexity of the real universe in which we live and the idealised order of physical theory. Careful observation of nature thus plays a powerful role in the creation of all scientific knowledge, and the subsequent development of technologies. Unambiguous understanding of the quality of data from experiment, whether from the detectors located within the caverns of the Large Hadron Collider at CERN, or from a handheld radiation counter, is critical for the effective use of the data. I will argue why radiation metrology is a critical component of all applied nuclear physics research and make the case for measurement to be placed at the forefront of our laboratory-based teaching programmes.

Nuclear Structure Studies / 14

New calculated reaction rates for the astrophysical rp-process reactions ^{34}S(p,γ)^{35}Cl and ^{34g,m}Cl(p,γ)^{35}Ar

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

Environmental Measurements / 15

Assessment of radon concentration levels in some dwellings in Serule area.

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A discovery of huge uranium deposits in the Serule area in Botswana leading to the prospects of mining explorations has since opened up various studies to be undertaken in the area. This study assesses the indoor radon concentration levels in Serule area and the radiological risk associated with it. ^{222}Rn is of interest since it is a daughter radionuclide of ^{226}Ra from the ^{238}U decay series and can cause adverse health problems such as lung cancer when inhaled. The radon concentration in the sampled houses was measured using special detectors called Electret Passive Environmental Radon Monitors (E-PERMs). The weighted mean average indoor radon concentration found to be 23.4 ± 2.1 Bq/m^3. Soil samples from the vicinity of the sampled houses were collected and gamma-ray counted using a High Purity Germanium (HPGe) detector at iThemba LABS. This was done to determine the activity concentration of ^{238}U, ^{232}Th and ^{40}K. Higher activity concentrations of ^{238}U were found in areas within the mining area. The activity concentrations of ^{232}Th were generally low and higher activity concentrations of ^{40}K were found in areas outside the mining area. The highest radium equivalent (Ra_{eq}) value calculated was from an area within the mining area but all the calculated Ra_{eq} values were well below the 370 Bq.kg^{-1} limit set by IAEA. Heavy metal concentrations in the soil samples were determined using the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) from the Central Analytical Facilities in Stellenbosch University. Nickel and cadmium concentrations from a dwelling outside the mining area were found to have values higher than the maximum allowable limit according to WHO/FAO guidelines. Ni and Cd were found to have concentration values of 109.282 mg/kg and 158.213 mg/kg respectively.

Environmental Measurements / **16**

Environmental radiation measurements enabling comparison of efficiency calibrations of HPGe detector with GEANT4

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A low background Hyper Pure Germanium detector was used to determine the radioactivity levels in soil samples collected from Southern area of Chad in Central Africa.
The calculated activity concentrations were determined for the following radionuclides: ^{226}Ra, ^{238}U and ^{232}Th as well as ^{40}K and ^{137}Cs (anthropogenic).
In order to validate our experimental result regarding efficiency calibration, GEANT4 Monte Carlo code was utilised to test the peak efficiency characterizations of ^{40}K, ^{22}Na, ^{137}Cs, ^{60}Co and ^{152}Eu. This comparison should show how the code agree with experimentally obtained efficiencies of our detector and in which part of the spectrum do the discrepancies appear.

Environmental Measurements / **18**

Application of nuclear interactions for material analysis: A case study of determination of metal contaminants from industrial effluents in North-West Nigeria using NAA technique

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Neutron Activation Analysis (NAA), a non-destructive nuclear analytical technique that meets the criteria of experimental simplicity, analytical accuracy and flexibility has been applied to investigate the metal contents of industrial effluents collected at several sites in North-Western part of Nigeria. Ten elements (Cr, Co, Ca, Na, Eu, Hf, Th, Dy, Sb and Cs) were determined from 10 samples from the leather, textile and petrochemical industries. The enrichment factors were determined by comparison of the elemental concentration with that of a typical soil from an uninhabited, uncultivated, non-industrial area within the same locality of the survey. The analytical result shows that some of the industrial effluents have high elevated concentration for chromium, calcium, cobalt, sodium, antimony, and dysprosium. The most distinct being chromium from the tanneries due to the chemical processing stage of leather products involving tanning with chrome. Certified reference material was used during the analyses as quality control to assure the analytical quality of the results. The successful application of this nuclear analytical technique during this study confirms its suitability to environmental studies and the applicability of the k0-NAA method in the Nigeria Research Reactor-1 (NIRR-1) laboratories.

Nuclear Structure Studies / **19**

Cross section measurement of light ions production using (p,xp) reactions.

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Neutron-rich beams are being developed at iThemba LABS to study nuclear structure away from stability. This is also the opportunity of deepening our understanding of astrophysical origin of elements. The interest of using (p,xp) reactions in the production of exotic nuclei, lies in the fact that proton beams have a large penetrating power and can be produced with high intensity. Some measurements have been performed at iThemba LABS using, 7Li, 9Be and natB targets with proton projectiles of energy 50 MeV and 66 MeV. The detection setup included 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. Some results will be presented. Beryllium and Boron are chosen here because they can be used in oxide, carbide or nitride form that can sustain large temperature amplitudes and therefore can be used in place as Uranium carbide in the current design of the ISOL source of iThemba LABS. This is important as there is no significant cost or resources implications. In addition, light targets produce a lot less species which makes debugging easier. The results of this investigation will be used to evaluate the feasibility of light neutron rich beams at iThemba LABS.

Nuclear Structure Studies / **20**

Studies of the Isoscalar Giant Quadrupole Resonance in stable even-even neodymium isotopes

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Fine structure has been studied on the region of the Isoscalar Giant Quadrupole Resonance (ISGQR), for stable even-even nuclei of neodymium isotopes. The 200 MeV proton beams were delivered by the Separated Sector Cyclotron (SSC) facility of iThemba LABS. Measurements were made using the state-of-the-art K600 magnetic spectrometer, where unique high energy-resolution (ΔE ≈ 42 - 48 keV FWHM) proton inelastic scattering results were obtained on spherical to deformed ^{142}Nd, ^{144}Nd, ^{146}Nd, ^{148}Nd and ^{150}Nd target nuclei. In order to emphasize the ISGQR in the measured excitation energy spectra, a Discrete Wavelet Transform (DWT) background subtraction was carried out. A comparison of the resonance widths extracted shows a systematic broadening of the ISGQR (Γ = 3.220 MeV to 5.100 MeV), moving from spherical ^{142}Nd to highly deformed ^{150}Nd nuclei. Theoretical microscopic Quasiparticle-Phonon Model (QPM) calculations were performed for the ISGQR predictions. Characteristic energy scales, extracted using the Continuous Wavelet Transform (CWT) technique, allowed a comparison to be made between the experimental data and theoretical predictions in order to determine the dominant damping mechanisms.

Nuclear Structure Studies / **21**

Spectroscopy of 50Ti through internal-pair formation

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Spectroscopy of ^{50}Ti through internal-pair formation

The excited states of atomic nuclei predominantly de-excite via electromagnetic transitions, e.g. gamma-ray transitions or electric monopole (E0) transition in an event that the former is forbidden. E0 transitions proceed via conversion electrons and electron-positron pairs (for transition energies greater than 1022 keV). In comparison to gamma-ray transitions that are predominantly studied across the nuclear chart, a great deal of E0 transitions and their associated excited 0^+ states are still not firmly characterized.

Apart from being the only alternative means of unambiguously assigning spin and parity of 0^+ states, E0 transitions also offer a reliable tool to explore shape coexistence in nuclei, as the E0 transition strength (ρ^2(E0)) is related to changes in the mean-square charge radius and can be used to calculate the mixing parameters for shapes suspected to be coexisting. Measurements of E0 transitions also helps to elucidate phenomena relating to nuclear compressibility and isotope or isomer shift, as well as provide sensitive tests on various models of nuclear structure [1,2,3,4].

A new facility, namely the internal conversion (IC) and internal-pair formation (IPF) spectrometer, for measuring E0 transitions, was recently commissioned at iThemba Laboratory for Accelerator Based Sciences (iThemba LABS). The current work is aimed at giving the equipment new capability by coupling a segmented germanium (LEPS) detector to the magnetic lens in order for it to be used to measure e^--e^+ pairs, including those of higher (> 3 MeV) energies. The LEPS detector is opted for owing to the fact that it offers very good resolution and also because of the scarcity (or exorbitant prices if found) of thick segmented Si(Li) detectors around the globe. The refurbishment is being aided by Geant4 simulations with magnetic field mapped out of the solenoid magnetic lens using OPERA-3D software. The transmission, efficiency, momentum resolution and other parameters of the spectrometer, obtained using Geant4 simulations, will be presented. On-going work to assemble the equipment, carry out off-line test measurements using radioactive sources (e.g. ^{90}Y or ^{13}C(α, n) radioactive sources), calibration, transmission optimisation, etc, in readiness for the upcoming in-beam experiment (^{50}Ti$(\alpha, \alpha^{'})$ and ^{48}Ca$(\alpha, 2n)$ reactions) in April 2020, will also be discussed.

Once the facility is fully operational, the physics case will involve measuring E0 transitions in ^{50}Ti through internal-pair decay, which will provide information that will subsequently be used to investigate the previously suspected existence of admixtures of 0^+ excited states with 2^+, 3^+ and 4^+ states [5,6,7].

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Environmental Measurements / 22

Gamma-ray spectroscopy and its associated radiological risk of beach sand and soil samples from Zanzibar, United Republic of Tanzania

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In this study, the activity concentration of natural radionuclides (K-40, and Th-232 and U-238 decay products) in beach sand and soil samples from Zanzibar were measured using a combination of in-situ and ex-situ gamma-ray spectroscopy. The in-situ gamma-ray survey was conducted using the Multi Element Detector for Underwater Sediment Activity (MEDUSA) detector. Activity concentrations of the natural radionuclides (K-40, and Th-232 and U-238 decay products) were extracted from the MEDUSA spectra using the Full Spectrum Analysis (FSA) procedure; and spatial distribution maps for K-40, Th-232 and U-238) were plotted. The collected beach sands and soil samples were analysed ex-situ using a Hyper-Purity Germanium detector (HPGe).

The activity concentration of K-40, and Th-232 and U-238 decay products in beach sands were found to have enhanced radioactivity levels due to the presence of heavy minerals. The spatial distribution maps for K-40, Th-232 and U-238 show large variation in xoil samples for the two relatively small islands, Unguja and Pemba.

The average outdoor absorbed gamma dose rate in air and annual effective dose equivalent were also calculated in this study. The highest abzorbed dose rates in xoil xamples and beach sand are respectively 5 and 38 times higher than the average world level of 57 nGy/h for terrestrial doses. The annual effective dose equivalent in most soil samples were higher than the world average value of 0.07 mSv/y; and low in most beach sands with an exception of black sand samples collected from Kukuu beach. From radiological point of view, there is no significant radiollgical risk for humans using Zanzibar beaches for various activities.

Nuclear Structure Studies / 23

Search for E0 transitions in even-even 54Cr and odd-odd 54Mn nuclei

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Between 40Ca and 56Ni, the most dominant physical feature emerging is super-deformation [1] and the open question that is yet to be answered with experimental evidence is, does the super-deformation follow through to 56Ni. There are also strong evidence from theoretical predictions that shape coexistence exist along the chain of N = 28 isotones, amid 56Ni and 48Ca [2, 3] as it is believed to exist throughout the nuclear chart [4]. Nevertheless, there is no experimental data available on E0 transitions in 50Ti and in neighbouring 52Ti, 54Cr, and 54Mn. In this study, the E0 strength which carry vital information about the nuclear structure have been determined in the and transitions of 54Mn for the first time, utilising pair and conversion-electron spectroscopy.

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Collaborations and Networking / 24

The Role of Inter-Africa UK Collaboration in Improving Nuclear Instrumentation for Research and Development in Africa

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Over the last decade, the role and importance of nuclear science and technology cannot be overestimated. Humankind have benefited from many advantages of nuclear technology including power production, health benefits, food, and environmental safety, agricultural development as well as security. Such benefits are the results of continuous research efforts and knowledge expansion in nuclear physics. The success of such researches requires the development of research and development (R&D) nuclear instrumentation. Reliable instrumentation for nuclear measurements is vital for the safe and effective use of several nuclear techniques and technology. Nevertheless, most developing countries are far behind developed countries in terms of nuclear instrumentation. This causes either lack of reliable nuclear researches or difficult conditions of doing nuclear researches in these countries leading to failure to take full advantage of the available nuclear technology, which could hugely boost the economies of these countries. In order to ease the situation, research collaborations between the less developed, developing and developed countries have always been suggested so as to take advantage of the available nuclear instruments. This makes nuclear instrumentation an important point of focus for collaborations between African countries and the United Kingdom (UK). This talk will highlight the importance of the inter-Africa and United Kingdom (UK) collaborations in the development of nuclear instrumentation and nuclear technology in Africa.

Environmental Measurements / 25

Design of a national indoor radon survey in South Africa: Radon measurements in homes and schools around Western Cape.

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Radon is a radioactive gas that is present in public buildings and homes. It comes from the natural decay of uranium in soil, rock, and water and gets into the air we breathe. Radon gas is believed to cause thousands of preventable lung cancer deaths every year. In 2018 the Centre for Nuclear Safety and Security (CNSS) initiated a project to design a national indoor radon survey in South Africa. One way of developing a national radon survey is to use potential maps of radon to identify hotspots areas. Indoor radon measurements have been performed in different schools and homes, and this has been achieved through school outreach. Electrets ion chambers were deployed for a week in homes and schools in different locations of selected areas. Here we report the findings of the indoor radon measurements conducted across Cape Flats in Western Cape.

Metrology and Applications / 26

DNA DSB repair pathways in mammalian cells – measurements and simulations

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The GEANT4 Monte Carlo simulation toolkit for radiobiology, GEANT4-DNA, developed earlier [Belov et al., 2015; 2017] is to be improved and extended. The stages of DNA double strand break (DSB) repair in mammalian cells will be verified by the reconstruction of the repair time courses of radiation induced foci, which are suited to specific repair processes.
The model shows a possible mechanistic explanation of the basic regularities of DSB processing through the non-homologous end-joining (NHEJ), homologous recombination (HR), single-strand annealing (SSA) and two alternative end-joining pathways.
New experimental data produced in the field will be incorporated during further development of the model. The new radiation modalities suggested for introduction into the model are protons, neutrons and alpha particles. The cells under investigation range from healthy fibroblast to cancer cells. The cell survival and repair mechanisms will be assessed, and results will be compared to those obtained from the extended GEANT4-DNA. Geant4-DNA will be applied for DSB repair in a wider range of human cell lines, ranging from healthy fibroblast to cancer cells. The cell culturing, radiation exposure, immunohistochemical staining of different DNA repair proteins and microscopic evaluation of the cells will be performed in the radiobiology laboratory at iThemba LABS using the Metafer automated microscope from Metasystems. The cells will be exposed to 222Rn as well as alpha particles, protons and neutrons. The dose accumulated due to 222Rn will be estimated by using a RAD7 detector from SU.
The developed model would be a more comprehensive version that incorporates recent findings and reconstructs DSB repair outcomes, induced by different radiation modalities. The cell survival and repair process will be assessed in the radiobiology laboratory at iThemba LABS and results compared to those obtained by the model.
The improved model will enhance our predictive capabilities and significantly contribute to the fields of medicine, radiation protection as well as space exploration

The MeASURe experience / **27**

Measurements and signal processing of energy and time signals of 22Na using LaBr3:Ce scintillation detectors

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Positronium (Ps) is a system consisting of an electron and its anti-particle, a positron, bound together into an exotic atom, specifically an onium. The system is unstable: the two particles annihilate each other to predominantly produce two or three gamma-rays, depending on the relative spin states. Even rarer decays (with branching ratios $<10^{-6}$) can be detected with a suitable array of sensitive detectors. Because of the small branching ratios, high count rates become imperative.

Measurements have been taken of a 10 μCi ^{22}Na radioisotopic source
using a pair of $LaBr_3$:Ce scintillation detectors. These detectors
combine good energy resolution with excellent timing resolution (~300 ps) which allow for quality time-of-flight measurements. Results focusing on the signal processing of both the timing (fast) and energy (slow) signals of these scintillation detectors will be presented, as well as the resulting energy and time spectra from ^{22}Na.

Environmental Measurements / **28**

Investigation of limit of detection using standard radioactive sources with a LaBr3(Ce) detector

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Investigation of limit of detection using standard radioactive sources with a LaBr3(Ce) detector
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Keywords: LaBr3(Ce) detector; Background radiation; Gamma radiation

Abstract

Ambient background radiation has been measured using a LaBr3(Ce) detector. This background gamma-radiation is mainly a result of construction materials (such as concrete) and air. Radionuclides that form part of the background have been identified after an energy calibration of the detector was performed using 22Na, 60Co and 152Eu radiation sources. These same sources have been measured at increasing distances from the detector. The study focussed mainly on the determination of the detection limits of each radiation source taking into account the presence of background radiation. Therefore, the change in the intensity measured for each source as a function of increasing distance from the detector has been emphasised. This application is in relation to the solid angle between the points of the radiation source and the active detector volume. Further studies and application of all data available will focus on the relevant factors in order to calculate the limit of detection for a specific activity for each radiation source.

This study forms part of a broader research project that entails the design, building and commissioning of a prototype mobile gamma-ray detection system equipped with a LaBr3(Ce) detector. The successful development of such a detector system will enable in situ measurements of radiation in various robust terrestrial environments with improved sensitivity and spectral resolution.

Collaborations and Networking / **29**

The AGATA Spectrometer: Precision Spectroscopy of Exotic Nuclei

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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. AGATA has been operated in a series of scientific campaigns at Legnaro National Laboratory in Italy and GSI in Germany and GANIL in France. The status of the project and an overview of the science results and programme will be presented.

Metrology and Applications / **30**

Radiobiological evaluation of secondary radiation produced in proton therapy

Authors: Charlot Vandevoorde[1]; Marijke De Saint-Hubert[2]; Philip Beukes[3]; Sabina Chiriotti[2]; Emily Debrot[4]; Evan de Kock[3]; C Lachlan[4]; Xanthene Miles[3]; Jaime Nieto-Camero[3]; Alessio Parisi[2]; Julyan Symons[3]; Anatoly Rosenfeld[4]; Lihn Tran[4]; Filip Vanhavere[2]; Olivier Van Hoey[2]

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To be completed

Metrology and Applications / 31

Influence of dose rate on the cellular response to neutrons and its implications for manned space missions

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To be completed

Environmental Measurements / 32

Dis-equilibrium in the 238U series and its significance to environmental analysis

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Environmental analysis of naturally occurring radionuclides is an important analytical requirement of a radio-analytical laboratory. This is true in South Africa, where mining is a huge part of the economic activity. Uranium-238 and its daughters contribute a large percentage in environmental assessments. A study was conducted on different naturally occurring radioactive material emissions to study the effect of dis-equilibrium in the 238U series and its impact on environmental radio-analysis. Coal, fly-ash, uranium ore, gold mine tailings and acid mine drainage samples were analyzed using a HPGe detector. The results showed that in most of the samples analyzed, there was no secular equilibrium in the 238U series with the exception of uranium ore samples. Therefore, it was concluded that analysis of the different nuclides in the 238U series is necessary for accurate results and that the common assumption that 226Ra is in equilibrium with 238U is incorrect and leads to incorrect results. The study recommends the analysis based on three major sub-series which develop within the 238U series: 238U - 234U, 226Ra - 214Po and 210Pb - 210Po

Nuclear Structure Studies / **33**

Lifetime measurements on A~100 nuclei using LaBr3(Ce) arrays.

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The region of the nuclear chart around neutron-rich A~100 nuclei is one where prolate and oblate nuclear shapes are predicted to be in close competition. An indirect measurement of the shape of the nucleus can be obtained from measuring level lifetimes which relate, via transition rates, to beta_2 deformation. In order to make measurements of level lifetimes in the sub nanosecond range an array of 36 LaBr3(Ce) detectors has been constructed for use at the FAIR facility in Darmstadt, Germany. This presentation will give an overview of the array and examples of its use in commissioning experiments at the RIKEN Nishina Center in Japan and the Argonne National Laboratory in the USA.

Posters / **34**

Development of 18F radiochemistry for tracer particle production at PEPT (Cape Town)

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Positron Emission Particle Tracking (PEPT) is a radioactive tracer technique used to track the trajectory of a radioactively labelled macroscopic particle using a variant of Positron Emission Tomography (PET). The primary application of PEPT is to study dynamic flow systems under varying conditions; including a wide range of particle size distributions, physical, and chemical properties (e.g. densities, shapes, surface chemistry, friction coefficients, etc.), with applications across the science disciplines. We are interested in developing 18F based tracer particles using both radiochemical and physical methods for PEPT applications.

For radiochemical tracer particle production, we are interested in extracting 18F from commercially available 18-fluorodeoxyglucose (18FDG) as well as exploring synthesis methods with ion-exchange techniques to label small phase-representative resin particles (diameter < 1 mm). For physical activation we will primarily be looking at the reaction 16O(alpha,pn)18F to produce positron emitters in-situ for larger particles (> 5 mm diameter).

This work will develop iThemba LABS specific tracer particle production mechanisms using 18F for the first time, and will provide insight into the effects of tracer particle properties in PEPT applications including optimisation of the PEPT technique and enhanced tracer production mechanisms.

Posters / **35**

PEPT study of minerals recovery using froth floatation

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At the heart of most mineral processing plants is froth flotation which is a physico-chemical separation method depending on differences in wettability between the valuable mineral and the non-valuable material. Air bubbles are introduced into a ground slurry where chemical reagents have been added to enhance the hydrophobicity of the desired mineral and exploit primarily the differences in the exposed surface properties. Coarse particle flotation has lately become attractive due to the lower energy requirement for particle size reduction. We study a separator which has anecdotally been show to produce results that are economically attractive for coarse sized particles.
This device is formed by a combination of fluidized bed and column flotation principles: hydrophilic particles are deemed heavy and follow a tortuous path downwards in the cell and settle in the lower dewatering zone and eventually are released as tailings for further downstream processing. In this work Positron Emission Particle Tracking (PEPT) is used to investigate the particle motion and its dynamic perturbation. PEPT is a Lagrangian single-particle tracking method used to measure the dynamics of a suitable radionuclide tracer introduced to the system. The particle size used for this study is +150μm diameter and the fluid-particle interaction in the system is investigated to gain a deeper understanding of the underlying physical principles in its operation.

Acclerator Mass Spectrometry / **36**

Late-Pleistocene Molluscan Bio-stratigraphy of Rusinga-Mfangano Island beaches, Lake Victoria-Kenya

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Lake Victoria, a fresh-water lake with an area of 69,484km2 has irregular quadrilateral shape on its shores, a length of 337km and breadth 240km, deeply indented coastline exceeding 3,220km. The waters fill a shallow depression, centered in the great plateau between the Western and Eastern Rift Valleys extending from Afar depression. The current lake's surface is 1,134m and a depth of 82m. It has numerous Islands with the Kenyan side as pelagic Rusinga and Mfangano Islands. We provide the deep and high lake level stands of Rusinga and Mfangano Islands from the Late Pleistocene molluscan biostratigraphic data of former low stand and high stand beaches. The first dated chronological sequence of molluscs of Rusinga and Mfangano Islands from the former beaches and high and low stands as fluctuations of the Lake Victorian levels from 340 yr BP to 40,000 yr BP. Low and older deep lake stands sequence almost as an abyssal plain in Nyakweri and Kogallo beach deposits, 3-4m beaches of Mfangano and Rusinga Islands dated 38100±934 and 25790±240yr BP respectively with molluscan species of Bellenya unicolar, Pila ovata, Bulinus cf. truncata and high older lake stand in Makira beach, 20-18m dominated with Corbicula fluminalis dated 34113- 35547yr BP in Mfangano Island. Lower and younger sequences in Wakula and Ulugi beaches, 3-4m, dated 400±58 and 450±43yr BP dominated with Biomphalaria cf. pfeifferi, Lymnaea natalensis and L. acuminata in Mfangano Island and Bellemya bengalensis in Rusinga Island and higher younger lake stands in Uuta beach, 12-14m beach deposit bearing Melanoides tuberculata, Bellamya constricta and B. unicolar dated 3510±61BP in Rusinga Island. Consequently some low stand beaches deposits depicted older basin and some high stand beach sediments depicted younger lakes hence evidences of geological progressive tilting and micro-fractural history caused by subsequent transgression and regression of the Late-Pleistocene sequences of Lake Victoria basin.

The MeASURe experience / **37**

Sub-Millimetre Positron-Emission Particle Tracking using a CdZnTe Semiconductor Array

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The Positron Emission Particle Tracking (PEPT) technique has been in development in Cape Town since 2009, and allows one to track a 1mm positron-emitting point source travelling at 1m/s to within 1mm, 1000 times a second. Traditionally, this utilises large scintillation Bismuth Germanium Oxide (BGO) arrays, which offer high intrinsic efficiency at 511keV (60-65\%) but low spatial resolution (4-5mm). An alternative approach is to use high energy resolution (2.87\%) CdZnTe semiconductor detectors with a higher spatial resolution (1.82mm) to track tracer particles to sub-millimetre precision. Measurements have located a low-activity (≈37kBq) ^{22}Na button source in three-dimensional space with an uncertainty of 0.11mm and a signal-to-noise ratio of 85\%. Using a 4-crystal CZT array, with each crystal measuring 20mm x 20mm x 10mm, a maximum coincidence rate of 60Hz was measured using a 2.22MBq ^{68}Ga source. The CZT array is therefore more appropriate to track very small tracer particles (≈10μm) which necessarily have lower activities than is optimal for conventional PEPT with the HR++ currently used at PEPT Cape Town. Additionally, using a larger 16 CZT crystal array a 1.2MBq ^{22}Na tracer particle was tracked at speeds of up to 20mm/s moving in circles of down to 1mm in diameter.

Nuclear Structure Studies / **38**

A study of the 12C(p,2p)11 B reaction at 200 MeV

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The interest in recent years in quasi-free scattering (QFS) originates from its utility as a tool to investigate single particle properties of unstable nuclei. However, the difference in quenched spectroscopic behaviour as a function of proton-neutron asymmetry observed between nucleon removal reactions on light nuclei e.g. 9Be(28S,27P), transfer reactions, and (p,pN) reactions in inverse kinematics would seem to imply that structure information depends strongly on the description of the reaction dynamics. For a better understanding of the reaction dynamics of QFS it is best to return to the experimentally less complicated direct kinematics meaurements. Especially now that

theoretical tools are available that can overcome limitations of the Distorted Wave Impulse Approximation (DWIA) traditionally used to describe QFS. Substantial deviations are observed between experimental and state of the art theoretical cross-sections for the 12C(p,2p)11B reaction at 400 MeV, as performed at RCNP. In order to disentangle the nuclear structure and reaction dynamics contribution to these deviations, it would be interesting to determine what happens at a lower beam energy of 200 MeV. In the near future an experiment will be performed at iThemba LABS to investigate quasi-free scattering to individual states in the residual 11B nucleus through the 12C(p,2p)11B reaction at 200 MeV. Coincident proton detection with the K600 magnetic spectrometer and a detector telescope is envisaged. Also, possible developments of a new coincident detector telescope system using LaBr detectors will be briefly explored.

Nuclear Structure Studies / **39**

Establishing the deformation characteristics and decay spectroscopy of ^{66}Ge

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Describing rapidly evolving nuclear deformation is important for determining the true behaviour of the strong force and to create accurate macroscopic-microscopic models of the nucleus. Current models suggest a change from soft shapes through triaxial deformation in ^{66}Ge. This nucleus lies in a particularly interesting region of the nuclear chart, with neutron numbers between the two shell closures $N = 28$ and 50, but also in a position above spherical nuclei at the shell closure $Z = 28$ and below deformed Se, Kr, and Sr isotopes. It is the next even-even isotope in the germanium chain after the $N = Z$ nucleus ^{64}Ge, and therefore, measurements in ^{66}Ge are important to predict deformation in this neutron-deficient region.

The measurement of the spectroscopic quadrupole moment Q_s for the first excitation 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. In order to accurately determine the beam purity, the beam was implanted on an

aluminium foil and let to decay. Information on the decay schemes of the daughter ^{66}Ga and granddaughter ^{66}Zn are also studied. Progress on the analysis of the Coulomb-excitation and β-decay data sets will be presented.

Nuclear Structure Studies / **40**

First direct measurement of the intrinsic dipole moment in pear-shaped thorium isotopes

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It is now well established that atomic nuclei composed of certain combinations of protons and neutrons can adopt reflection-asymmetric, or octupole-deformed, shapes at low excitation energy. These nuclei show promise in the search for a permanent atomic electric dipole moment, the existence of which has implications for physics beyond the Standard Model. Theoretical studies have suggested that certain isotopes of thorium may have the largest octupole deformation. However, due to experimental challenges, the extent of the octupole collectivity in the low-energy states in these thorium nuclei has not yet been demonstrated. This paper reports measurements of the lifetimes of low-energy states in ^{228}Th ($Z = 90$) undertaken using the mirror symmetric centroid difference method and a natural thorium source. Lifetime measurements of the low-lying $J^{\pi} = 1^{-}$ and 3^{-} states, which are the first for a thorium isotope, have allowed the $B(E1)$ rates and the intrinsic dipole moment to be determined. The results are in agreement with those of previous theoretical calculations allowing the extent of the octupole deformation of ^{228}Th to be estimated. This study indicates that the nuclei ^{229}Th and ^{229}Pa ($Z = 91$) may be good candidates for the search for a permanent atomic electric dipole moment. The potential to extend such source measurements at iThemba Labs will be discussed.

The MeASURe experience / **41**

Expanding PEPT applications with tracer techniques

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Positron emission particle tracking (PEPT) is a non-invasive tracking technique best used in understanding the fundamental physics within opaque multiphase flow systems. This dedicated research facility is situated within iThemba LABS and requires accurate and representative tracers to mimic the behaviour of the material of interest for a system under study. This presentation divulges the development of tracers and the impact in the field of applied nuclear techniques by reporting the historical and current techniques used to make them.

Environmental Measurements / **42**

Compton Camera Imaging for Environmental Purposes

Authors: Helen Boston[1]; Tom Woodroof[1]

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On 11th March 2011 the Fukushima Daiichi nuclear power plant suffered major damage after being hit by a magnitude 9 earthquake and subsequent tsunami. This resulted in a major radionuclide release to the environment. In response to this, remediation of the surrounding agricultural land commenced.

Part of the scientific focus is on understanding the dynamics of 137Cs, in terms of plant uptake and retention in soils. Accurate quantification of activities for sources whose distributions vary spatially and temporally is required.

At the University of Liverpool, UK we have characterised the near-field response of our Compton camera Gamma-Ray Imager (GRI) system to enable accurate estimation of 137Cs activity and its location.

The ability to precisely determine activity and distribution at small scales (sub-cm resolution in a sub-metre phase space) is considered to have applications beyond studying the dynamics of radiocaesium in environmental media.

At present, activity can be reliably estimated from the event rate for point-like sources, and a method to derive activity for distributed sources from the reconstructed Compton images is in development.

The characterisation and validation study of the system performance will be presented.

Environmental Measurements / **43**

Radon in the mines

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High radon levels are found in the underground mines in South Africa. The CNSS has decided to fund a project to study ways of improving the regulations for the large number of underground miners in South Africa.

This presentation will consider some of the issues related to this study.

The MeASURe experience / **44**

Monte Carlo Simulations of the iThemba LABS Neutron Beam Facility

Author: Zina Ndabeni[1]

Co-authors: Peane Maleka [2]; Ricky Smit [2]; Andy Buffler [3]; Tanya Hutton [4]; Thomas Leadbeater [4]

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iThemba LABS fast neutron beam facility (D-line vault) is one of the two facilities in the world that can provide quasi mono-energetic neutron beams in the energy from about 30 MeV to 200 MeV. The vault is currently undergoing an upgrade and development in order for it to meet the requirements for a medium and high-energy neutron metrology facility. One of the major challenges identified from the previous set-up was the epithermal neutron background due to leakage from the target area to the experimental area. As part of the ongoing refurbishment, to reduce epithermal background in the experimental area, Monte Carlo (MC) simulations aimed at benchmarking experimental data from previous investigations of the neutron background inside the vault are being conducted and will be presented.

[1] M. Mosconi et al., "Characterisation of the high-energy neutron beam at iThemba LABS", Radiat. Meas., vol 45, pp. 1342-1345, 2010. doi:10.1016/j.radmeas.2010.06.044

Acclerator Mass Spectrometry / **45**

The Upgrade of the iThemba LABS Neutron Beam Facility

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iThemba LABS fast neutron beam facility (D-line vault) is one of the experimental vaults in the subatomic physics department. The vault has remained virtually unchanged since it was built and first became operational in the late 1980s [1]. The facility was nominated by the National Metrology Institute of South Africa (NMISA) and Bureau International des Poids et Mesures (BIPM) to be a "designated metrology institute for medium and high-energy neutron measurements" in South Africa. As a result, it is currently undergoing a major upgrade and development with the aim of achieving ISO-accreditation as a fast neutron beam reference facility. For this contribution, discussions based on challenges of the previous set-up as well as how these have been improved in the new set-up will be presented.
[1] J. C. Cornell, G. C. W. Lloyd and D. T. Fourie. "A neutron beam facility at NAC", in Proc. 12th International Conference on Cyclotrons and Their Applications (CYCLOTRONS 89), Berlin, Germany, May 1989, World Scientific Publishing Co., Singapore, 1991, pp. 594-597. http://accelconf.web.cern.ch/AccelConf/c89/p08.pdf

Collaborations and Networking / **46**

A network for the measurement of radionuclide contaminants in water and soil

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Ground water and soil contamination can have a significant impact on the health and wellbeing of local communities. In remote or poor, under-resourced areas, where water treatment and regulation is not always feasible, the impact of contamination is increased. In rural communities based for example around agriculture and fishing, contaminants can be easily ingested by people directly from the water source, through contaminated fish and animals, through crops etc. The amount of contaminants can be enhanced through man-made activities such as mining, chemical processing and pesticide drift.
One type of contamination is through the presence of radioactive material. Naturally Occurring Radioactive Material (NORM) can be found everywhere from bedrocks, water and even in some food sources like bananas and brazil nuts. However, human activity can increase the amount of radionuclides in nature, the so called Technologically Enhanced Radioactive Materials (TENORM). Mining, smelting, and the coal and oil industries are some of the major sources of TENORM.
An extensive network for the measurement of background radiation in water and soil can help us map the presence of NORM and TENORM in African countries. Such a project can provide valuable information to inform regulating authorities and legislators on the environmental impact of man-made activities, provide benchmark values for NORM from regions with low anthropogenic impact and identify regions with potentially harmful amounts of radionuclides. These measurements can also act as the starting point for further research on for example the long-term impact of industry to local communities.
Various techniques can be used to measure and monitor the presence and emission of radionuclides. For example, permanent and mobile radiation monitoring systems, small-scale airborne detectors and chemical analysis.
In this presentation we will introduce the concept of such a broad measurement network. The aim is to identify possible stakeholders and their needs, in order to establish such a network and pursue funding.

Nuclear Structure Studies / **47**

E1 strength measurements at iThemba LABS

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iThemba LABS, South Africa, is a suitable laboratory for the experimental study of the E1 strength in nuclei. The K600 magnetic spectrometer is one of the few spectrometers in the region of 30-200 MeV with high-energy resolution and the ability to perform measurements at zero degrees. This capability enabled the study of fine structure in giant resonances and the role of deformation in these collective modes. The recent development of coincidence measurements of charged particle and γ-ray decays is a perfect combination for investigating the nature of the pygmy dipole resonance and broad excited structures in detail.

Photo-absorption cross sections and decay branching ratios of nuclei lighter than 56Fe be measured by forward-angle proton inelastic scattering with the K600 magnetic spectrometer coupled to the charged particle detector CAKE and gamma spectrometer ALBA. These experiments will be part of an international joint project PANDORA (Photo-Absorption of Nuclei and Decay Observation for Reactions in Astrophysics), aiming at systematic measurement on electric dipole excitation strengths and decay properties of stable nuclei below the mass of A=56. The project is primarily motivated by the study of the photo-disintegration and energy loss processes of ultra-high energy cosmic ray (UHECR) nuclei in extra-galactic propagation.

In this talk, I will present recent results of experiments conducted at iThemba LABS on giant and pygmy resonances and I will give a brief overview of the PANDORA project.

Posters / 48

Teaching the fundamentals of measurement and the SI: a triptych of posters

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On 16 November 2018 the member states of the Convention of the Metre agreed at the 26th General Conference on Weights and Measures to a revision to the international measurement system that underpins all global science and trade. On World Metrology Day, 20 May 2019, the SI unit system underwent the most significant change since its conception. The revised system means that measurements are not linked to physical artefacts or atomic material properties, but to the unchanging fundamental properties of nature itself.

We have designed three posters which present the foundations of measurement, metrology, the constants of nature and the Revised SI to high school and university students. The posters are free to download for use by educators and students. We are planning to produce teaching and learning materials to introduce the fundamentals of measurement at high school level. Ideas and discussion welcome.

Posters / 49

A Study on Codes and Standards used for Nuclear Grade Concrete

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In order to increase the lifetime of the Koeberg Nuclear Power Plant (NPP) civil structures it is imperative to consider enhanced aging management that includes examination, inspection, maintenance and testing of concrete that provide safety and structural functions. Reinforced concrete is the dominant civil engineering construction material for nuclear power plant structures. South Africa does not have its own codes and standards for the manufacture of nuclear grade concrete that covers all aspects, such as the design, commissioning, inspection, testing and installation. Construction of high quality concrete structures in the nuclear industry is a key requirement due to the high integrity demands on concrete performance, to resist seismic, thermal and other normal operating demands such as radiation, plant faults e.g. anticipated operating occurrence or accident conditions to extreme environmental loading attributed to internal or external events. Many concrete elements in the plant become effectively inaccessible once it is operational due to high levels of radiation. Some countries have adopted local ISO accredited codes of practice for structural properties of concrete, consistent with specific requirements of the nuclear industry [1-3]. This desktop review assessed the French and US nuclear regulatory regime relating to nuclear grade concrete for the purpose of safety and structural functions in nuclear installations. This will inform any recommendations that the National Nuclear Regulator (NNR) may develop in relation to local engineering codes and standards for same applications.

References
[1]. ICRP. ICRP Publication 103. Ann. ICRP 37, 2 (2007)
[2]. NESCC Concrete Task Group, Concrete Codes and Standards for Nuclear Power Plants, NIST, ANSI, (2011)
[3]. R D Bucur et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 246 012036

Posters / **52**

A new Instrumental Neutron Activation Analysis facility at UCT

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Instrumental Neutron Activation Analysis (INAA) is one of the most sensitive techniques to non-destructively determine the isotopic composition of a sample. The sensitivity of the technique is determined by the isotope of interest, intensity of the neutron source and neutron energy spectrum. In the case of thermal neutron irradiation with a nuclear reactor the minimum detection limits tend towards the level of ppb. We are in the process of implementing a new INAA facility within the Metrological and Applied Sciences University Research Unit (MeASURe) in the Department of Physics, University of Cape Town. The n-lab currently offers two neutron sources, a D-T sealed tube neutron generator (STNG) and radioisotopic 241Am/9Be source. The STNG produces mono-energetic neutrons of around 14 MeV, with an intensity of 10E8 neutrons per second, and the 220 GBq AmBe source produces neutrons with a broad energy spectrum, ranging from thermal to 11 MeV.

The first experimental phase will determine the limits of detection for a range of isotopes with the existing experimental set-up. This will be supplemented with simulation driven designs for neutron moderators, multipliers and reflectors in order to lower these limits.

Nuclear Structure Studies / **53**

Nuclear structure studies of low-lying states in 194Os using fast-timing coincidence gamma-ray spectroscopy

Authors: Terver Daniel[1]; Patrick Regan[2]; S Kisyov[3]; N Marginean[3]; Zsolt Podolyak[4]; Marginean R[3]; K Nomura[5]; R Mihai[3]; V Werner[6]; RJ Carroll[4]; L Gurgi[4]; Matthias Rudigier[7]; A Oprea[3]; T Berry[4]; A Serbau[3]; C Nita[3]; R Suvaila[3]; A Turturica[3]; C Costache[3]; I Stan[3]; A Olacel[3]; M Bolomiza[3]; S Toma[3]

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The properties of excited states in the neutron-rich nucleus 194Os have been investigated using the 192Os(18O, 16O)194Os 2 neutron transfer reaction using a 80 MeV 18O heavy-ion beam provided by the tandem van de Graaff accelerator at the IFIN-HH laboratory Bucharest. Discrete γ-ray decays from excited states have been measured using the hybrid HPGe-LaBr3 (Ce) γ-ray spectroscopic array RoSPHERE. The timing and energy response of the RoSPHERE system have been evaluated using a number of point radioactive sources and through other nuclear reaction products formed from reactions on minor target contaminants as well as via unsafe Coulomb excitation on the 192Os target. The work identifies a number of previously unreported low lying non-yrast states in 194 Os as well as the first B(E2;2 + ⟶ 0 +) measurement for this nucleus. The experimental results are compared with FB/IBM calculations and are consistent with a reduction in a quadrupole collectivity in Os isotopes with increasing N.

Keywords: RoSPHERE, Coincidence, Gamma-ray array, Spectrometer, high-purity germanium, lanthanum tribromide scintillators, matrix elements and time difference.

Acclerator Mass Spectrometry / **54**

CologneAMS lab report: Routine operation and some recent developments

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The first part of this talk gives an overview of the AMS system at the 6 MV accelerator of CologneAMS and discusses the performance of routine measurements for Be, C, Al, Cl, Ca and Pu. We focus on the suppression of the isobars B, S and K which are present in the case of Be, Cl and Ca and show corresponding spectra.

The second part of the talk discusses some special developments. We show a method for measuring ultra tiny radiocarbon samples. By using a spike it is possible to measure a 1 mug carbon sample with an uncertainty not bigger than the statistical limit. Another special development is taking place at the 10 MV accelerator of Cologne. We explain the AMS beam line which is suitable for the measurement of medium mass isotopes like Mn and Fe. One application for Fe is the search for supernovae near the solar system. This is very challenging since extremely small isotopic ratios have to be measured and one has to deal with the isobar Ni. We show our recent investigation of beam formation in a gas filled magnet for isobar suppression.

Acclerator Mass Spectrometry / **55**

Does Accelerator Mass Spectrometry have a place in an emerging economy?

Author: Woodborne Stephan[1]

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South Africa's science infrastructure is required to respond to a mandate that specifies a number of outcomes, and one of the core tenets is that science must impact on wellbeing in the country.

Extremely expensive science platforms, such as the recently commissioned Accelerator Mass Spectrometry (AMS) facility at iThemba LABS, must respond by facilitating research for users; by training the next generation of scientists; and by leading cutting edge research with a local benefit. The AMS facility is the only one of its kind on the African continent and will grow to serve not only the South African science community, but also the wider African community until it has a continental footprint. In meeting the mandate the AMS facility must operate in a partnership with the user base, both in the provision of know-how to run analyses on a science agenda set by the users, but also in leading in-house research that accommodates academic partners and facilitates post-graduate student participation. Many of the societal benefits of AMS are not to be found in the particle physics domain, but rather in the applied science that falls in to other disciplines. The basis of these applications is in the systematics of rare element production, decay and distribution among different reservoirs. Scientists at iThemba LABS are partnering with users who require traditional chronology-based applications of AMS, but they are also using the AMS facility across a wide range of novel applied domains. These include: testing climate change forecasts, dating groundwater recharge, assessing global phenomenon such as magnetic field fluctuations over the last 50 000 years. The essence of the program is to use particle physics for the benefit of the people of South Africa, and Africa.

Welcome / **57**

Director's Welcome

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Welcome / **58**

HoD Welcome

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Welcome / **59**

British Council

Environmental Measurements / **60**

Study of Chemical Composition and Radiation Attenuation Properties of Quartzite of Pouma-Cameroon

Author: Daniel BONGUE[1]

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In Cameroon, the quartzites mined in the locality of Pouma are frequently used as decorative stones for the interior and exterior embellishment of residential houses. We wanted to know if these beautiful decorative stones could also be good gamma attenuators, in which case, they could be used in hospitals, and research centers, to cover the walls of rooms in which we could store devices producing ionizing radiation. Thus, one could combine the useful with the pleasant by exploiting both

the beauty of these stones and their power of attenuation. Since their purchase price is extremely low, we could at the same time significantly reduce the cost of fitting out a radiation shielded room. To achieve this, nineteen (19) rock samples were collected from four (04) sites. The analysis of their chemical compositions was done using an energy dispersion spectrometer SPECTRO XEPOS version 5 belonging to the National Agency for Radioprotection (ANRP) of Cameroon. The mass attenuation coefficients were obtained in the standard energy range (1 KeV at 100 GeV), from the tabulated values, contained in the XCOM database, accessible by internet on the website of NIST (National Institute of Standards and Technology) agency, owned by the United States Department of Commerce. It appears from this study that the quartzite Pouma are mainly composed of SiO2, Al2O3, K2O, Fe2O3, CaO and P2O5. Dense, high atomic number materials such as iron, lead or uranium exist in puma quarzites, only in the form of traces, making them very poor attenuators of gamma radiation. Consequently, they can be used to decorate rooms, but not to attenuate gamma radiation.

Posters / **62**

Development of a digital data acquisition system for neutron metrology

Author: Chloé Sole[1]

Co-authors: Andy Buffler [2]; Richard Babut [3]; Tanya Hutton [4]; Thomas Leadbeater [4]; Vincent Gressier [3]

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Fast neutron fields are found in a wide variety of contexts, for example at accelerator and medical radiation facilities, around nuclear power plants, in airplanes in flight and space stations. These fields often vary widely with respect to both energy and intensity which complicates measurements of energy dependent fluence. Bonner sphere systems remain widely in use, although systems based on scintillator detectors offer distinct advantages including improved energy resolution on the fast neutron energy range (above 1 MeV). Since scintillators are typically sensitive to all types of radiation, including gamma rays, it is necessary to select neutron-only events, and pulse shape discrimination capabilities of selected scintillators is typically used for this purpose. Digital pulse processing electronics offer several distinct advantages over analogue systems, including being more cost effective and compact, but most importantly the flexibility of analyzing raw pulses in list mode.

Within the neutron metrology and spectrometry community digital pulse processing systems are being developed for a variety of purposes. New digital data acquisition systems need to be benchmarked against the current metrology standards, typically based on analogue systems. We present a comparison between the IRSN fast neutron metrology analogue acquisition system to an off-the-shelf CAEN desktop digitizer. Measurements were made using a BC-501A scintillator detector at IRSN AMANDE accelerator based facility. Uncertainty budgets for measurements of neutron energy dependent fluence distributions are compared for the analogue and digital acquisition systems. The broader aim of this project is to further the development of a digital data acquisition system for fast neutron metrology using advanced scintillator technology for use in neutron fields where time-of-flight may or may not be available.

Posters / **63**

Monte Carlo Simulations of the iThemba LABS Neutron Beam Facility

Author: Zina Ndabeni[1]

Co-authors: Peane Maleka [2]; Ricky Smit [2]; Andy Buffler [3]; Tanya Hutton [4]; Thomas Leadbeater [4]

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The MeASURe experience / 64

Monte Carlo Simulations of the iThemba LABS Neutron Beam Facility

Author: Zina Ndabeni[1]

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Posters / 65

Measurements and signal processing of energy and time signals of 22Na using LaBr3:Ce scintillation detectors

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Positronium (Ps) is a system consisting of an electron and its anti-particle, a positron, bound together into an exotic atom, specifically an onium. The system is unstable: the two particles annihilate each other to predominantly produce two or three gamma-rays, depending on the relative spin states. Even rarer decays (with branching ratios $<10^{-6}$) can be detected with a suitable array of sensitive detectors. Because of the small branching ratios, high count rates become imperative.

Measurements have been taken of a 10 μCi ^{22}Na radioisotopic source
using a pair of $LaBr_3$:Ce scintillation detectors. These detectors
combine good energy resolution with excellent timing resolution (~300 ps) which allow for quality time-of-flight measurements. Results focusing on the signal processing of both the timing (fast) and energy (slow) signals of these scintillation detectors will be presented, as well as the resulting energy and time spectra from ^{22}Na.

Posters / **66**

Expanding PEPT applications with tracer techniques

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Positron emission particle tracking (PEPT) is a non-invasive tracking technique best used in understanding the fundamental physics within opaque multiphase flow systems. This dedicated research facility is situated within iThemba LABS and requires accurate and representative tracers to mimic the behaviour of the material of interest for a system under study. This presentation divulges the development of tracers and the impact in the field of applied nuclear techniques by reporting the historical and current techniques used to make them.

Posters / **67**

Sub-Millimetre Positron-Emission Particle Tracking using a CdZnTe Semiconductor Array

Authors: Nicholas Hyslop[None]; Thomas Leadbeater[1]; Steve Peterson[1]

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The Positron Emission Particle Tracking (PEPT) technique has been in development in Cape Town since 2009, and allows one to track a 1mm positron-emitting point source travelling at 1m/s to within

1mm, 1000 times a second. Traditionally, this utilises large scintillation Bismuth Germanium Oxide (BGO) arrays, which offer high intrinsic efficiency at 511keV (60-65\%) but low spatial resolution (4-5mm). An alternative approach is to use high energy resolution (2.87\%) CdZnTe semiconductor detectors with a higher spatial resolution (1.82mm) to track tracer particles to sub-millimetre precision. Measurements have located a low-activity (≈37kBq) ^{22}Na button source in three-dimensional space with an uncertainty of 0.11mm and a signal-to-noise ratio of 85\%. Using a 4-crystal CZT array, with each crystal measuring 20mm x 20mm x 10mm, a maximum coincidence rate of 60Hz was measured using a 2.22MBq ^{68}Ga source. The CZT array is therefore more appropriate to track very small tracer particles (≈10μm) which necessarily have lower activities than is optimal for conventional PEPT with the HR++ currently used at PEPT Cape Town. Additionally, using a larger 16 CZT crystal array a 1.2MBq ^{22}Na tracer particle was tracked at speeds of up to 20mm/s moving in circles of down to 1mm in diameter.

Metrology and Applications / **68**

Role of NMISA in society

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The dti established agencies that form part of its technical infrastructure (standards, quality assurance and metrology) in order:

- To address market failures through technical regulations in order to protect the public and the environment and by providing standards and accreditation to regulators as policy tools.
- To support industrial development through:
- development and maintenance of sector specific South African National Standards (SANS)
- providing traceability of measurement,
- accrediting service providers that provide testing, certification and verification services to industry that needs to prove compliance with regulations and standards.

NMISA is part of the technical infrastructure and provides measurement support to the South African community through its metrology capabilities. The presentation will highlight the role of NMISA and how it supports the South Africans and neighbouring countries through measurements that are linked to the international measurement system.

Posters / **69**

Prompt Gamma Imaging: Verifying Proton Therapy Treatment Dose

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Prompt Gamma Imaging (PGI) focuses on the detection of secondary (prompt) gammas during a proton therapy treatment. With the use of a Compton camera, PGI is working to create an in-vivo image of the dose deposited within the patient as a dose verification system. I will present an overview of

Prompt Gamma Imaging at UCT, the UCT POLARIS detection system and the current work being performed. I will also discuss the next steps towards the development of PGI and our role in the larger project to develop a complete clinical system.

Posters / 70

A new reference detector for fast neutron metrology

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A new reference detector for fast neutron metrology is being developed. A modern detector system based on pulse shape discrimination (PSD) plastic scintillation, compact silicon photomultipliers (SiPMs) and digital pulse processing. A main goal is to design, construct and characterize a prototype of a new fast scintillator detector suitable for fast neutron spectroscopy over the range of 0.5 MeV to 200 MeV. The detector will form part of the redevelopment of the fast neutron facility (D-Vault) at iThemba LABS and will be used in the intercomparison studies for ISO-17025 accreditation. Measurements will be made within the n-lab in UCT Physics, the fast neutron facility at iThemba LABS and AMANDE facility at IRSN in Cadarache, France.

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Development of a digital data acquisition system for neutron metrology

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Fast neutron fields are found in a wide variety of contexts, for example at accelerator and medical radiation facilities, around nuclear power plants, in airplanes in flight and space stations. These fields often vary widely with respect to both energy and intensity which complicates measurements of energy dependent fluence. Bonner sphere systems remain widely in use, although systems based on scintillator detectors offer distinct advantages including improved energy resolution on the fast neutron energy range (above 1 MeV). Since scintillators are typically sensitive to all types of radiation, including gamma rays, it is necessary to select neutron-only events, and pulse shape discrimination capabilities of selected scintillators is typically used for this purpose. Digital pulse processing electronics offer several distinct advantages over analogue systems, including being more cost effective and compact, but most importantly the flexibility of analyzing raw pulses in list mode.

Within the neutron metrology and spectrometry community digital pulse processing systems are being developed for a variety of purposes. New digital data acquisition systems need to be benchmarked against the current metrology standards, typically based on analogue systems. We present

a comparison between the IRSN fast neutron metrology analogue acquisition system to an off-the-shelf CAEN desktop digitizer. Measurements were made using a BC-501A scintillator detector at IRSN AMANDE accelerator based facility. Uncertainty budgets for measurements of neutron energy dependent fluence distributions are compared for the analogue and digital acquisition systems. The broader aim of this project is to further the development of a digital data acquisition system for fast neutron metrology using advanced scintillator technology for use in neutron fields where time-of-flight may or may not be available.

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Measurements and signal processing of energy and time signals of 22Na using LaBr3:Ce scintillation detectors

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Positronium (Ps) is a system consisting of an electron and its anti-particle, a positron, bound together into an exotic atom, specifically an onium. The system is unstable: the two particles annihilate each other to predominantly produce two or three gamma-rays, depending on the relative spin states. Even rarer decays (with branching ratios $<10^{-6}$) can be detected with a suitable array of sensitive detectors. Because of the small branching ratios, high count rates become imperative.

Measurements have been taken of a 10 μCi ^{22}Na radioisotopic source
using a pair of $LaBr_3$:Ce scintillation detectors. These detectors
combine good energy resolution with excellent timing resolution (~300 ps) which allow for quality time-of-flight measurements. Results focusing on the signal processing of both the timing (fast) and energy (slow) signals of these scintillation detectors will be presented, as well as the resulting energy and time spectra from ^{22}Na.

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Expanding PEPT applications with tracer techniques

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Positron emission particle tracking (PEPT) is a non-invasive tracking technique best used in understanding the fundamental physics within opaque multiphase flow systems. This dedicated research facility is situated within iThemba LABS and requires accurate and representative tracers to mimic the behaviour of the material of interest for a system under study. This presentation divulges the development of tracers and the impact in the field of applied nuclear techniques by reporting the historical and current techniques used to make them.

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Sub-Millimetre Positron-Emission Particle Tracking using a CdZnTe Semiconductor Array

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The Positron Emission Particle Tracking (PEPT) technique has been in development in Cape Town since 2009, and allows one to track a 1mm positron-emitting point source travelling at 1m/s to within 1mm, 1000 times a second. Traditionally, this utilises large scintillation Bismuth Germanium Oxide (BGO) arrays, which offer high intrinsic efficiency at 511keV (60-65\%) but low spatial resolution (4-5mm). An alternative approach is to use high energy resolution (2.87\%) CdZnTe semiconductor detectors with a higher spatial resolution (1.82mm) to track tracer particles to sub-millimetre precision. Measurements have located a low-activity ($\approx$37kBq) ^{22}Na button source in three-dimensional space with an uncertainty of 0.11mm and a signal-to-noise ratio of 85\%. Using a 4-crystal CZT array, with each crystal measuring 20mm x 20mm x 10mm, a maximum coincidence rate of 60Hz was measured using a 2.22MBq ^{68}Ga source. The CZT array is therefore more appropriate to track very small tracer particles ($\approx 10\mu$m) which necessarily have lower activities than is optimal for conventional PEPT with the HR++ currently used at PEPT Cape Town. Additionally, using a larger 16 CZT crystal array a 1.2MBq ^{22}Na tracer particle was tracked at speeds of up to 20mm/s moving in circles of down to 1mm in diameter.

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A new reference detector for fast neutron metrology

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A new reference detector for fast neutron metrology is being developed. A modern detector system based on pulse shape discrimination (PSD) plastic scintillation, compact silicon photomultipliers (SiPMs) and digital pulse processing. A main goal is to design, construct and characterize a prototype of a new fast scintillator detector suitable for fast neutron spectroscopy over the range of 0.5 MeV to 200 MeV. The detector will form part of the redevelopment of the fast neutron facility (D-Vault) at iThemba LABS and will be used in the intercomparison studies for ISO-17025 accreditation. Measurements will be made within the n-lab in UCT Physics, the fast neutron facility at iThemba LABS and AMANDE facility at IRSN in Cadarache, France.

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PEPT study of minerals recovery using froth floatation

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At the heart of most mineral processing plants is froth flotation which is a physico-chemical separation method depending on differences in wettability between the valuable mineral and the non-valuable material. Air bubbles are introduced into a ground slurry where chemical reagents have been added to enhance the hydrophobicity of the desired mineral and exploit primarily the differences in the exposed surface properties. Coarse particle flotation has lately become attractive due to the lower energy requirement for particle size reduction. We study a separator which has anecdotally been show to produce results that are economically attractive for coarse sized particles.
This device is formed by a combination of fluidized bed and column flotation principles: hydrophilic particles are deemed heavy and follow a tortuous path downwards in the cell and settle in the lower dewatering zone and eventually are released as tailings for further downstream processing. In this work Positron Emission Particle Tracking (PEPT) is used to investigate the particle motion and its dynamic perturbation. PEPT is a Lagrangian single-particle tracking method used to measure the dynamics of a suitable radionuclide tracer introduced to the system. The particle size used for this study is +150μm diameter and the fluid-particle interaction in the system is investigated to gain a deeper understanding of the underlying physical principles in its operation.

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A new Instrumental Neutron Activation Analysis facility at UCT

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Instrumental Neutron Activation Analysis (INAA) is one of the most sensitive techniques to non-destructively determine the isotopic composition of a sample. The sensitivity of the technique is determined by the isotope of interest, intensity of the neutron source and neutron energy spectrum. In the case of thermal neutron irradiation with a nuclear reactor the minimum detection limits tend towards the level of ppb. We are in the process of implementing a new INAA facility within the Metrological and Applied Sciences University Research Unit (MeASURe) in the Department of Physics, University of Cape Town. The n-lab currently offers two neutron sources, a D-T sealed tube neutron generator (STNG) and radioisotopic 241Am/9Be source. The STNG produces mono-energetic neutrons of around 14 MeV, with an intensity of 10E8 neutrons per second, and the 220 GBq AmBe source produces neutrons with a broad energy spectrum, ranging from thermal to 11 MeV.

The first experimental phase will determine the limits of detection for a range of isotopes with the existing experimental set-up. This will be supplemented with simulation driven designs for neutron moderators, multipliers and reflectors in order to lower these limits.

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Development of 18F radiochemistry for tracer particle production at PEPT (Cape Town)

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Positron Emission Particle Tracking (PEPT) is a radioactive tracer technique used to track the trajectory of a radioactively labelled macroscopic particle using a variant of Positron Emission Tomography (PET). The primary application of PEPT is to study dynamic flow systems under varying conditions; including a wide range of particle size distributions, physical, and chemical properties (e.g. densities, shapes, surface chemistry, friction coefficients, etc.), with applications across the science disciplines. We are interested in developing 18F based tracer particles using both radiochemical and physical methods for PEPT applications.

For radiochemical tracer particle production, we are interested in extracting 18F from commercially available 18-fluorodeoxyglucose (18FDG) as well as exploring synthesis methods with ion-exchange techniques to label small phase-representative resin particles (diameter < 1 mm). For physical activation we will primarily be looking at the reaction 16O(alpha,pn)18F to produce positron emitters in-situ for larger particles (> 5 mm diameter).

This work will develop iThemba LABS specific tracer particle production mechanisms using 18F for the first time, and will provide insight into the effects of tracer particle properties in PEPT applications including optimisation of the PEPT technique and enhanced tracer production mechanisms.

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Gamma-ray line production cross sections in interaction of high energy protons with target nuclei of astrophysical interest: intercomparison of experimental data measured at the SSC facility over the incident proton energy range, Ep = 30 - 200 MeV.

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In this presentation, we report differential cross section results for some ɣ-ray lines produced in the nuclear reactions 56Fe (p, xɣ) (lines at Eɣ =1238 and 1408 keV), NatMg (p ,xɣ) (lines at Eɣ = 440 and 450 keV) and NatSi (p, xɣ) (line at Eɣ = 781 keV). These results are part of our analysis of the PR 239 experiment, carried out in 2015 at iThemba LABS with proton beams of energies, Ep = 66, 80,

95, 110 and 125 MeV using the high energy-resolution Compton-suppressed AFRODITE detection array.

An inter-comparison is made between counterpart experimental data sets measured within our joint collaboration at the SSC facility of iThemba LABS over the whole investigated incident proton energy range, Ep = 30 - 200 MeV for checking their reliability and coherence. The harvest of γ-ray line production cross section experimental results obtained in the framework of this collaboration are new, reported for the first time. They can be pertinently used for simulating still not elucidated astrophysical processes like the interactions of low energy cosmic rays in the inner galaxy, and for determining the properties of γ-ray line emitting astrophysical sites such Solar flares and the ISM.

Keywords : High energy proton beams, HPGe clover detectors, γ-ray line production cross sections; Solar flares, ISM.

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Measurement of gamma-ray line production cross sections from residual nuclei produced in natCa (p, x) nuclear reactions. Comparison of the results to theoretical predictions.

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Gamma-ray energy spectra from the de-excitation of residual nuclei produced in irradiations of a calcium target with proton beams of energies, Ep = 30, 42, 54 and 66 MeV, have been recorded

using the iThemba LABS AFRODITE array equipped with 8 Compton-suppressed HPGe clover detectors. The areas of characteristic peaks for de-excitation gamma-ray lines from low-lying states of several nuclei - 40Ca (line at 3737 keV), 39Ca (2796 keV line), 39K (2522 and 2814 keV lines), 38K (328 keV line), 38Ar (2167 keV line) and 37Ar (1410 and 1611 keV lines) - have been extracted from which integrated line production cross sections have been determined via Legendre-polynomial fits to the angular distribution experimental data. The obtained results were then compared to TALYS code calculations in order to estimate the contributions of different reaction mechanisms. Following calculations using the TALYS code default input parameters, fair agreements between theory and experiment are observed for the lines at E = 328 keV and 1611 keV, while large discrepancies ranging from 25 % up to 100 % are found for the other lines. Significant improvements are achieved following our TALYS calculations performed with using in the latter code modified Optical Model Potential (OMP) parameters and applying the Level Density (LD) model.

Preliminary cross-section experimental results are presented here, together with data available in the literature measured for 40Ca at proton energies, Ep = 66, 80, 95, 110 and 125 MeV, compared to theory via TALYS code calculations.

Keywords: Nuclear reactions, γ-ray production cross sections, TALYS code calculations, optical model potential.

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Radioisotope tracer techniques for the study of multiphase flows

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At iThemba LABS Positron Emission Particle Tracking (PEPT) is used to study dynamic physical processes and multiphase flow phenomena. Studies of these often turbulent systems contribute to understanding of fundamental flow behaviour and are of increasing interest in the current climate of reducing industrial wastes, improving process efficiencies, and developing design lead approaches to industrial systems. PEPT results are critical for the evaluation of computational models of such phenomena.

In the spirit of the previous ANSTT meetings we will update on recent research produced by the PEPT Cape Town laboratory, including aspects of our four key themes: instrumentation & detector development, radioisotope tracer techniques (physical and chemical), data acquisition & processing, and the applications of such measurements. Noting that such Advanced Nuclear Science, Technology, Techniques, and ultimately their applications, are large scale multidisciplinary endeavours there will be a strong focus on our role in personnel development and training involving researchers from a diverse range of backgrounds. We will offer thoughts into collaboration building around these techniques, particularly in the application phase space.

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Design and construction of a gamma-ray spectrometer with water shielding for low-level natural occurring radioactive material measurement

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Gamma-ray spectrometer with a single HPGe or NaI:Tl detector shielded with lead is often used to measure the activity concentration of radionuclides in soil samples. A passive water shield to reduce background radiation reaching the detectors was designed using GEANT4 Monte Carlo simulations and then constructed. IAEA-375 soil and beach sand each placed in Marinelli beaker were measured for 48 hours using two LaBr3:Ce detectors placed inside the constructed water shield. The samples were also measured for 24 hours using a NaI:Tl detector inside the constructed water shield and HPGe shielded with lead and copper to compare and validate the results from measurements with the LaBr3:Ce detectors. Both the simulated and measured results show that the water shield attenuates the 2614.5 keV gamma rays by over 90 % and energies lower than the 2614.5 keV by far above 90 %. The activity concentration of K-40 radionuclide in IAEA-375 soil and beach sand measured using the LaBr3:Ce detectors was below the minimum detectable activity (MDA) due to the internal activity of the detector. The measured activity concentrations of U-238 and Th-232 series and K-40 radionuclides in IAEA-375 soil were comparable with certified values to within measurement uncertainties. The activity concentrations of U-238 and Th-232 series radionuclides in beach sand were determined using all the measurement geometries and consistent to within 1σ to 2σ level.

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Modern African Nuclear DEtector LAboratories at UWC/UNIZULU

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As part of a Global Funding/STFC collaboration between the Universities of the Western Cape (UWC) and Zululand (UNIZULU) in South Africa and the University of York in the UK, two nuclear laboratories are being built at UWC and UNIZULU and extensive student training and technology transfer on particle detectors, digital systems and GEANT simulations is being carried out at the University of York. The goal is to create modern laboratories where state-of-the-art research on new detector development can be carried out by SA students and researchers. Developments include fast digital systems (CAEN and XIA) to be used with plastic scintillators for medical applications or the study of underground radiation in the Richards Bay large industrial area. Additionally, the development of new detectors systems to be coupled with the GAMKA array for fundamental research (including SiC, ionization chamber, etc) and simulations with GEANT4 on the Cloud are also crucial parts of our program.

Environmental Measurements / **84**

In-situ gamma-ray mapping with the MEDUSA detector system - some applications in South Africa

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The MEDUSA in-situ gamma-ray spectrometry system makes use of, amongst others, a CsI detector and GPS-signal receiver to generate radioactivity maps. The system can be used on land, under water and for aerial surveys. The use of this system to tudy mine tailings, terroir (linked to wine production), and anthropogenic environmental radioactivity in South Africa will be discussed.

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The SAINTS@tlabs - empowering through education, training and experience: an overview

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The SAINTS (Southern African Institute for Nuclear Technology and Sciences) operates like a department at iThemba LABS NRF. It is developing an education and training programme to benefit, in the first instance, post-graduate students that are using research facilities at iThemba LABS for their research.

The SAINTS vision is that its programme will significantly improve the key performance indicators (e.g. quality of dissertations/publications, completion time for degrees, impact of research) related to student training. The SAINTS programme is being developed by a formal consortium of partners (local universities, international research centres and international training institutes).

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The South African Young Nuclear Professionals Society (SAYNPS)

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The South African Young Nuclear Professionals Society (SAYNPS) is a registered non-profit organisation established in 2002 after the second biannual conference of the International Youth Nuclear Congress (IYNC) in Dae-Jung, South Korea. The society was established with the main objectives of promoting the South African nuclear industry both locally and internationally by ensuring effective and adequate participation of South African youth in nuclear related activities, educating youth about career opportunities within the nuclear industry, expose young nuclear professionals to other international nuclear professionals activities through participation in International fora, form part of the global network of young nuclear professionals and perform outreach campaigns aimed at informing the public about the importance of nuclear science and technology in the society. SAYNPs subscribes to the African Young Generation in Nuclear (AYGN) and the International Youth Nuclear Congress (IYNC). These international bodies were created to ensure that skills transfer and development is realized in the nuclear sector for Young Professionals so as to mitigate against the loss of highly experienced professionals when they retire. Over the years, SAYNPS membership has grown significantly. SAYNPS has also extended its membership to various universities offering nuclear and radiation sciences related curriculum (e.g. North West University, Sefako Makgatho Health Sciences University, University of Limpopo, etc.). The aim is to extend the student chapters across

institutions of higher learning with the country.As a non-profit organisation, SAYNPS achieves its mandate and its objectives through direct organisational and institutional support including availability of resources from stakeholders such as Eskom, South African Energy Corporation (NECSA), iThemba Labs (tLabs), Department of Minerals Resources and Energy (DMRE), the National Nuclear Regulator (NNR), National Radioactive Waste Disposal Institute (NRWDI) , Nuclear Industry Association of South Africa (NIASA) and other stakeholders. Since 2002, SAYNPS continues to perform outreach activities at various schools and communities across the country.

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MLEM & Ray Tracing Image Reconstruction Techniques for UCT PET Detector.

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At UCT, positron imaging techniques are used to investigate systems of flow for science and engineering applications. As an example, positron emission tomography (PET) measurements are performed of the distribution of liquid in 2D flowing foams to investigate bubble coalescence in mineral froth flotation. The impact of the results and the feasibility of more complex measurements, such as extending the results to 3D and multiphase media, are limited by the simplicity of the image reconstruction techniques and uncertainties around the longer range of the positron in the gas phase. The goal of this preliminary study is to develop an advanced image reconstruction technique, namely maximum-likelihood expectation-maximisation (MLEM), for the PET camera configuration at UCT. PET measurements were performed on a point sorce on the surface of a cylinder and of a helix structure wound around a cylinder. The images were reconstructed with both MLEM and a simple back projection algorithm to ascertain the ability of the technique to reconstruct three-dimensional images. This is a promising first step towards the investigation of bubble coalescence in 3D; the next stage of which will be achieved with Géant 4 simulation of the PET camera and a spherical shell radiolabeled with a positron emitting radionuclide.