SAINTS | SAIF | G-IRI | TIP

iThemba LABS

HIGHLIGHTS & ACHIEVEMENTS

2019 - 2021

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

NRF
National Research Foundation
iThemba LABS
Laboratory for Accelerator Based Sciences

CONTENTS

EXECUTIVE SUMMARY

The Long-Range Plan was drafted in 2017 and gives expression to iThemba LABS's vision for the next 10 years. The plan is built on FOUR pillars, namely the Southern African Institute for Nuclear Technology and Sciences (SAINTS), the South African Isotope Facility (SAIF), the Gateway to International Research Infrastructure (G-iRi) and the Technology and Innovation Platform (TIP). These pillars are KEY strategic objectives that support the facility's research, education and training agenda. iThemba LABS's vision is to improve the lives of ALL South Africans and to contribute to a BETTER world through the pursuit of basic science and innovation. It provides an enabling research environment that is globally recognized for its excellence and expertise in Accelerator-Based Science, a place where knowledge is advanced in service of society. This report not only provides valuable feedback on the progress that has been made with regard to the Long-Range Plan, but also communicates important milestones that have been reached with regard to research and the education and training of the next generation of scientists and technicians. A number of new or improved research facilities have become available in recent years, thereby expanding the range of applications of accelerators at iThemba LABS. Most prominent among these are the Accelerator Mass Spectrometry (AMS) facility, the new 3-MV Tandetron for materials research, the refurbished fast-neutron beam facility, the building of a dedicated radiation biophysics beamline and the significant increase in γ-ray detection capabilities with ALBA, the completion of AFRODITE decades after its establishment and the combination of both ALBA and AFRODITE as the GAMKA array. New detector configurations have been added that allow for the gamma-ray arrays to be used in conjunction with the existing K=600 magnetic spectrometer to advance certain niche research activities.

We cannot ignore that towards the middle of the year, the COVID-19 pandemic hit the world and the country in a very dramatic way. For iThemba LABS, this has been a major factor in slowing down the progress made towards completing the implementation of the LRP towards the middle of 2023. The SAIF project has been managed as a priority, and besides potential challenges in funding provision that were not foreseen, no major delay is expected. Both TIP and the LERIB (Low Energy Radioactive Ion Beam) facility have been suffering from a significant reduction in human resource deployment due to the pandemic.

HEALTH
AND SAFETY

The RSHEQ department was established at the start of 2018 primarily to ensure that iThemba LABS complies with all regulatory policies and acts that govern its operation. These include:

- Radiation Protection (RP) – Hazardous substances (Act No. 15 of 1973, relating to Group III electronic products producing ionizing radiation and Group IV radioactive material)
- Safety Health and Environment (SHE) – meeting the operational requirements for a safe and healthy working environment as outlined in the Occupational Health and Safety Act (Act No. 85 of 1993)
- Physical Security – the provision of loss control, physical facility security and nuclear/radiological security in terms of the Private Security Industry Regulatory Act (PSIRA) (Act No. 56 of 2001)

The establishment of the department for Radiation, Safety, Health, Environment and Quality (RSHEQ), which integrates Safety and Security functions, is in line with the International Atomic Energy Agency (IAEA) guiding principles. The merger of the functions under a quality management umbrella has promoted a shift from ad hoc safety and security practices to a proceduralized system of Radiation Protection and Occupational Health and Safety. This intrasectional engagement platform is in support of the progression to a standardised, certifiable quality management system. One of the major impacts of the RSHEQ department was in drafting a document to articulate our operational response to the restrictions imposed by the lockdown due to the COVID-19 pandemic. The document, which forms part of our business continuity plan, is based on the hierarchy of controls, and evolved into distinct protocols covering engineering interventions, staff/student density management, mandatory hygiene practices, case management, symptom screening, medical disclosures and PPE provisions. In addition, a dedicated communication channel to the in-house COVID Response Team was established, as well as an Employee Assistance Programme to cover social aspects brought on by the pandemic, supported by a team of healthcare workers.

In order to minimize the infection risk to the essential worker cohort, a facility occupancy scheme was devised that considered the risk of being infected in both the internal and external environments. The scheme was linked to the National State of Disaster Alert Level plan to ensure that we were able to ramp on-site activities up or down in response to economic sector activity permissions. The following practices were suggested, based on the specific alert level:

Level 5:
Drastic measures to contain the spread of the virus, i.e. lockdown

- Staff work from home, with the exception of those permitted on site and involved in essential service delivery.
- No experiments
- No students, users or visitors on site

Level 4:
Extreme precautions to limit community transmission
and outbreaks, while allowing some activities to resume

- Staff work from home, with the exception of those permitted and involved in essential service delivery and critical projects.
- No experiments
- No students, users or visitors on site

Level 3:
Restrictions on several activities, including at
workplaces and socially, to address a high risk of transmission

- Staff work from home OR, where achievable, according to a rotational scheme with 33,3% of staff at work.
- Commissioning and test experiments linked to the three accelerators, namely the SSC, Tandem and Tandetron, but WITHOUT external users' involvement on site
- Essential Radiobiology and Nanoscience experiments allowed (with prior approval)

- Postdocs – same as for staff
- Students may be allowed on site to participate in experiments or to use infrastructure to facilitate video conferencing with their iThemba LABS supervisors (limited to one student per supervisor on duty – in line with density targets).
- No users or visitors on site

Level 2:
Physical distancing and restrictions on leisure
and social activities to prevent a resurgence of the virus

- Staff rotation with 50% of staff at work
- Experiments to resume without external users' involvement on site
- Postdocs – same as for staff
- Students may be allowed on site to participate in experiments or to use infrastructure to facilitate video conferencing with their iThemba LABS supervisors (limited to two students per supervisor on duty – in line with density targets)
- No users or visitors on site

Level 1:
Most normal activities able to resume, with precautions
and health guidelines followed at all times

- Phased return to 80% occupancy on site in a structured manner, cognizant of the internal as well as external environmental risk
- Postdocs – same as for staff
- Experiments to be allowed to run without external users' involvement on site
- Students may be allowed on site to participate in experiments or to use infrastructure to facilitate video conferencing with their iThemba LABS supervisors – in line with density targets.
- No users or visitors, unless authorised by the director

PROGRESS WITH REGARDS TO THE LONG-RANGE PLAN (LRP)

SAINTS - SOUTHERN AFRICAN INSTITUTE FOR NUCLEAR TECHNOLOGY AND SCIENCES

The (student) training activities at iThemba LABS have been consolidated under the umbrella of the Southern African Institute for Nuclear Technology and Sciences (SAINTS) to bolster the human capacity development initiatives. iThemba LABS is committed to advance science by investing in the next generation of scientists and technicians. Not only do we need to raise awareness and appreciation of the contribution that the scientific endeavour makes to build a scientifically literate society, but we also need to facilitate access to infrastructure and opportunities. SAINTS, with the slogan “Empowerment through education, training and experience”, offers a range of activities that include workshops and masterclasses to assist young people in accessing opportunities linked to research and technical competence. SAINTS has positioned itself within the Higher Education sector through the Physics Summer School and the Spectrum, Presentation, Analysis, Manipulation and Simulation (SPAMS) workshop. The SPAMS workshop was offered virtually in 2021 and was attended by 19 participants (mostly master’s and doctoral students) from SA, Nigeria, Botswana, Cameroon, Egypt and Zambia.

SAINTS has identified a number of courses to be offered to postgraduate students on a regular basis. The availability of remote platforms has opened the possibility of offering the courses to bigger audiences both nationally and internationally. The courses, which focus on the research activities at iThemba LABS, include:

- Radiation interaction and detection
- Radiation protection
- Radiation biophysics
- Accelerator physics
- Ion-beam analysis techniques
- Nuclear Astrophysics
- Nuclear Reactions
- Nuclear Structure
- Accelerator Mass Spectrometry
- Monte Carlo Radiation Transport Modelling
- Data Analysis

The SAINTS initiative has formalized agreements with a number of universities to ensure that mutually beneficial interventions are offered. In addition, the SAINTS initiative has facilitated access to research infrastructure for a number of students through the provision of financial support in the form of scholarships, top-up funding and travel grants.

SAIF - SOUTH AFRICAN ISOTOPE FACILITY

The 200-MeV Separated Sector Cyclotron (SSC) currently provides stable beams to service the basic and applied research agenda, as well as the production of radiopharmaceuticals. The available beamtime is normally shared between the two groups in a 40:60 ratio. The impact of the COVID-19 lockdown restrictions and the classification of the production facility as an essential service led to the available beam being allocated mostly to isotope production in 2020/21. The iThemba LABS

radioisotopes programme is a world-class effort that has developed over a period of many years. The accelerator facilities allow for the production of a number of important radioisotopes, and the Good Manufacturing Practice (GMP) production capabilities allow for these products to be exported for clinical use. Routine isotope production has continued under the stringent lockdown restrictions, and we have been able to maintain supply agreements for 82Sr, 68Ge/68Ga generators, 18F-FDG, 22Na, 123I and 67Ga. 82Sr, which is used for PET imaging; the 68Ge/68Ga generators, used for PET imaging of neuroendocrine tumours, prostate cancer and infection/inflammation; and 22Na, used for positron annihilation studies, are produced for the international market, and service some 100 global clients. The 123I and 67Ga that are used as SPECT tracers, and the 18F-FDG that is used for cardiac and neurological applications, are produced solely for 25 local clients. iThemba LABS is capable of producing 18F-FDG on demand, due to the availability of a dedicated 11-MeV cyclotron. It is hoped that working relations with universities

and clinics in Cape Town will be strengthened in the coming years to expand the use of 18F-FDG for imaging oncology and neurological conditions. More than 1 300 consignments are dispatched annually, and these are used to manage more than 100 000 patients, of which 10 000 are local.

We were able to complete some upgrades to our infrastructure to adhere to GMP protocols, which included the addition of two biohazard cabinets, four clean rooms, a microlab with class 1 000 specification, and six pass boxes for use in the clean rooms and microlab.

The establishment of the South African Isotope Facility (SAIF) entails the acquisition of a dedicated 70-MeV cyclotron for isotope production. The Cyclone-70 cyclotron with four complete beamlines was ordered from IBA Radiopharma Solutions in September 2019. The C70 cyclotron can provide H- beams with energies from 35 MeV to 70 MeV and 750 µA total extracted current. The cyclotron is equipped with two extraction ports, each delivering up to 375 µA beam current independently of the other. This will not only enable iThemba LABS to increase its production capability for sought-after radioisotope products, but it will also free up the SSC for dedicated use as a tool for basic and applied research. Advances made on the SAIF project during 2020/21 include infrastructure development, design and fabrication of the beamline equipment, design of the target station and the securing of the necessary legal approvals from the various South African departments. To date, iThemba has secured licences to import and install the cyclotron. The cyclotron was successfully assembled and acceptance tested at IBA-Radiopharma Solutions in Belgium in July 2021. The cyclotron is expected to arrive in South Africa at the end of 2021, with on-site rigging scheduled for the beginning of 2022. We are already in the process of applying for the licence to operate the cyclotron.

The construction of the necessary infrastructure and modifications to the existing vaults where the cyclotron and beamlines will be installed, commenced in May 2021. The manufacturing of the target stations and other associated beamline equipment has also commenced to coincide with the installation and commissioning of the cyclotron in the first half of 2022.

Image (above): Design drawing with a view of the north-facing facade of the TIP building

TIP - TECHNOLOGY INNOVATION PLATFORM

Researchers at iThemba LABS are at the forefront of development and innovation through their participation in experimental physics programmes both locally and internationally. The Technology Innovation Platform (TIP) aims to create opportunities for researchers and technicians to engage with the industry, not only to facilitate the synergy, but also to explore possibilities linked to commercialization of ideas and products. A building (see an artist's impression above) that houses TIP will be constructed at the Cape Town site in 2021/22. TIP will have state-of-the-art facilities such as clean rooms for the manufacturing of electronics boards, semi-conducting and gaseous tracking detectors, sensors, highly integrated electronics and a big data/machine learning laboratory. It is envisaged that TIP will provide a test station for advanced detectors and electronics required by subatomic physics research, both locally and internationally. Through TIP, iThemba LABS will increase the involvement of South African institutions in the upgrade projects of international research facilities, which will in turn promote the transfer of skills and technology to South Africa.

A key component of TIP will be the facilitation of exchange programmes between collaborating institutions such as CERN, JINR, FAIR-GSI and BNL to share expertise and best practices linked to new technologies. It is envisaged that TIP will become the creative hub where research scientists, engineers and technicians

come together to find innovative and novel solutions for upgrade projects at the various institutions. The interplay between TIP and local industry will create a vehicle through which the general public become aware of the impact of innovation within the South African context.

The initial focus of TIP will be on the development of speciality electronics for application in data processing and Artificial Intelligence (AI), and detectors (gas counter, segmented Germanium and radiation detectors) for nuclear science and low-energy particle detection at the K600 spectrometer. Artificial Intelligence and data mining have become buzzwords in recent years, and it was therefore also decided to create a TIP focus at the Johannesburg site of iThemba LABS, namely at the Tandem and AMS laboratory.

G-IRI - GATEWAY TO INTERNATIONAL RESEARCH INFRASTRUCTURE

iThemba LABS is committed to become Africa's GATEWAY to International Research Infrastructure by providing an incubator within which young research scientists and technicians can be trained and upskilled to address the myriad of challenges faced by our country, our continent and the world. As an internationally competitive research facility, iThemba LABS has a global reputation that has been built over the years by developing and nurturing strong collaborative linkages and networking partnerships with the majority, if not all, of the nuclear research facilities across America, Australia, Asia and Europe. Moreover, iThemba LABS plays a critical role as an institutional host of South Africa's associate membership of the Joint Institute of Nuclear Research (JINR) in Dubna, and the South Africa-CERN collaboration. These strategic networks and international collaborations have been enriched over the last few years by similar collaborative agreements with GSI-FAIR and ELI-NP. iThemba LABS is furthermore actively involved in shaping the global strategy for Nuclear Physics and its Applications as a member of IUPAP-WG9 (International Union of Physics and Applied Physics – Working Group 9) and as an associate member of NuPECC (Nuclear Physics European Collaboration Committee).

STAKEHOLDER RELATIONS
AND COOPERATION

INTERNATIONAL COLLABORATIONS

- iThemba LABS researchers, through the SA-CERN consortium, are involved in ALICE and ISOLDE experiments at CERN, as well as in ATLAS experiments through a joint appointment at WITS. The ALICE group uses the Large Hadron Collider (LHC) to study the properties of nuclear matter known as Quark-Gluon Plasma (QGP), which is created in heavy-ion collisions under extreme conditions of temperature and energy density. iThemba LABS researchers are also using radioactive ion beams at HIE-ISOLDE to complement the research conducted with stable beams at iThemba LABS.
- iThemba LABS researchers are participating in the PANDORA (Photo-Absorption of Nuclei and Decay Observation for Reactions in Astrophysics) collaboration. The aim of the PANDORA project is to provide experimental data on the nuclear physics quantities needed for the astrophysical source models. This goal will be achieved through a joint experimental project among three facilities: iThemba LABS in South Africa, the Research Center for Nuclear Physics (RCNP) in Japan, and the Extreme Light Infrastructure – Nuclear Physics (ELI–NP) in Romania. A two-day (virtual) workshop was held by the collaboration on 30 June – 1 July 2020. The workshop served to update collaborators on progress made by the various participants and to explore possibilities linked to future research.
- iThemba LABS is part of the Nuclear Shapes and Resonances in Research and Education (NUCRED), funded by the International Partnerships for Excellent Education and Research (INTPART) programme. The NUCRED collaboration utilizes the experimental facilities at iThemba LABS, the Oslo Cyclotron Laboratory, and ISOLDE at CERN to study resonances in the photon strength function (PSF) as a function of the underlying nuclear structure effects. Experimental measurements of resonances in the PSF provide data that can be used to refine theoretical nuclear structure models and that is at the same time highly relevant for nuclear astrophysics and nuclear energy applications.
- iThemba LABS is part of the NuMEN (Nuclear Matrix Elements for Neutrinoless double beta decay) collaboration. The NuMEN collaboration will result in the focal plane detector from the MAGNEX spectrometer in the INFN-Laboratori Nazionali del Sud, (LNS) Catania, Italy, being installed on the K600 spectrometer at iThemba LABS. This will, for the first time, allow for the detection of heavy ions with the spectrometer, which signals the start of new research programmes being considered in SA. It is envisaged that the experience and expertise of the collaborators from the INFN-LNS will advance our efforts to build a new Focal Plane Detector at iThemba LABS.

ALICE DEVELOPMENT AND TESTING FACILITY

iThemba LABS actively supports the infrastructure development of ALICE (a large ion collider experiment) through its participation in the upgrades of the muon spectrometer. The second-long shutdown (2019/20) was used to upgrade the muon spectrometer to exploit the increased luminosity of the upgraded LHC of up to 50 000 Pb-Pb collisions per second. The upgrade to the spectrometer implied modifications to the Muon Identifier (MID) and the Muon Tracking Chamber (MCH) detectors. The upgrade of the MID included the replacement of the front-end and read-out to increase the maximum read-out rate. iThemba LABS developed the firmware for the MID common read-out unit (CRU), which includes the set-up of the CRU read-out test bench and the development of the user logic code that runs in the FPGA of the CRU. In addition, the MCH received new front-end and read-out

electronics to match the increased LHC luminosity. iThemba LABS participated in the replacement of the on-detector front-end electronics and implemented the low-voltage supply system. This included not only the design of the overall system and tests of the selected components under realistic magnetic field and radiation conditions, but also the implementation of the detector control system software to control and monitor the power supplies.

CONFERENCES: SHARING KNOWLEDGE AND SHOWCASING EXCELLENCE

iThemba LABS hosted the 2nd Conference on Neutrino and Nuclear Physics (CNNP) on 24–28 February 2020 at the African Pride Arabella Hotel & Spa near Kleinmond, South Africa. The conference was attended by 111 delegates, including 20 SA students. The conference promoted collaboration between scientists from the fields of nuclear, neutrino, astro- and dark-matter physics, and created an environment where the interplay between experiments and theories could be discussed. Research linked to the detection of neutrinos in South Africa dates back to the 1960s through the work of Reines and Sellschop. They used a liquid scintillator in the East Rand Proprietary Mine, 3 288 m below the surface, to make the first observation of cosmic-ray-induced neutrinos.

RESEARCH EXCELLENCE
AT ITHEMBA LABS

iThemba LABS is the largest particle accelerator facility in the southern hemisphere. The research laboratories are located at two sites, one in Cape Town and the other in Johannesburg. The facility has a staff complement of 270, of which 30 are full-time researchers and 15 postdoctoral fellows. The research capacity was further boosted through two joint appointments at South African universities and Universities of Technology. These appointments are Dr Zina Ndabeni from the University of Cape Town, with specialization in Neutron Physics, and Prof. Mandla Msimang from the Tshwane University of Technology, with specialization in Ion-Beam Analysis. In addition, Dr Lindsay Donaldson joined the subatomic physics group.

INFRASTRUCTURE

The research activities are spread over three accelerator laboratories and facilitated by stable beams from the 200-MeV Separated Sector Cyclotron (SSC), the 3-MV Tandetron and the 6-MV Tandem.

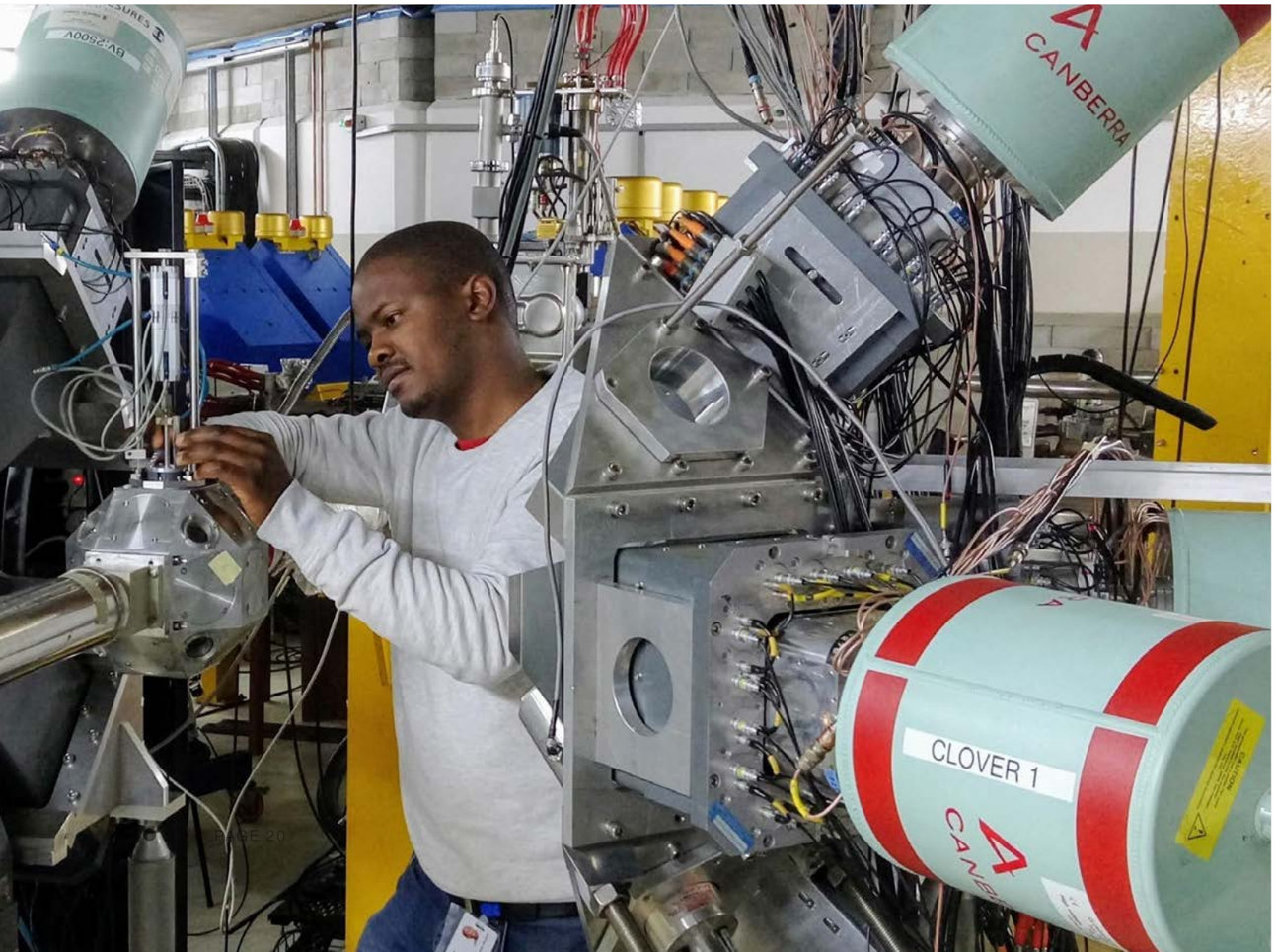
FUNDAMENTAL STUDIES WITH THE SEPARATED SECTOR CYCLOTRON (SSC)

The SSC is a variable energy machine, capable of accelerating protons to a maximum beam energy of 200 MeV. The SSC is fed by two injector cyclotrons (SPC1 and SPC2) that pre-accelerate the projectiles to 8 and 10 MeV/nucleon respectively. The two injector cyclotrons are equipped with an ECR-Ion Source (Electron Cyclotron Resonance) and PIG-Ion Source (Penning Induction Gauge) respectively.

The accelerated particle beams available from the SSC laboratory are used for studies linked to the structure, reactions and origin of nuclear matter in the universe (fundamental studies), the applications of nuclear techniques in metrology and

detector calibration (applied studies), the interaction of radiation with biological systems (radiation biophysics) and the production of new radiopharmaceuticals (radioisotope production). The research activities are driven by eight full-time researchers and eight postdoctoral fellows. Projects are offered to successful students, and in 2020 a total of 49 students were co-supervised by the research staff. The researchers were able to publish 17 peer-reviewed articles in 2019 and another 12 in 2020. There are currently 35 projects for which beamtime was awarded by the Programme Advisory Committee. This amounts to roughly 4 200 hours of operation.

The competitive nature of the research programme is informed by the range of available particle beams and the detection capabilities at iThemba LABS.



Gamma-ray detection systems

iThemba LABS has a wide range of gamma-ray detectors available, and the list is growing through investment and collaborations with international facilities. These include background-shielded single-crystal high-purity germanium (HPGe) detectors for activation or environmental radiation studies, segmented Clover detectors, eight HPGe low-energy photon detectors (LEPS), eight fast-timing 2” x 2” LaBr3:Ce detectors, and the AFRODITE and ALBA detector arrays. In addition, a range of ancillary detectors are available, which include:

- the refurbished Siegbahn-Kleinheinz electron spectrometer with a field of Bmax ~0.15 T and Si(Li) detectors of 5–6 mm thickness
- the β-decay tape station with a single-spool design and 50 m of 12 mm-wide mylar tape
- S1, S3 or W-type silicon detectors ranging in thickness from 140 µm to 1 000 µm
- CsI charged-particle detectors
- recoil detectors
- neutron detectors with time-of-flight discrimination of neutron-reaction channels

AFRODITE+PLUS

(African Omni-purpose Detector for Innovative Techniques and Experiments) is a gamma-ray array consisting of 17 Compton suppressed HPGe Clover detectors. The array provides experimentalists with improved detection efficiency and resolution.

ALBA

(African LaBr3:Ce Array) consists of 21 high-efficiency large-volume (89 x 203 mm) LaBr3:Ce detectors. This array provides the high-efficiencies for the studies of gamma-ray decay of resonances at high excitation energies or photon strength function measurements.

ALBA and AFRODITE+PLUS

May be run stand-alone or combined in any of the two new frames, namely Soccer-ball and Dandelion. The new frames have been designed to accommodate the detectors at variable distances from the target position.

GAMKA

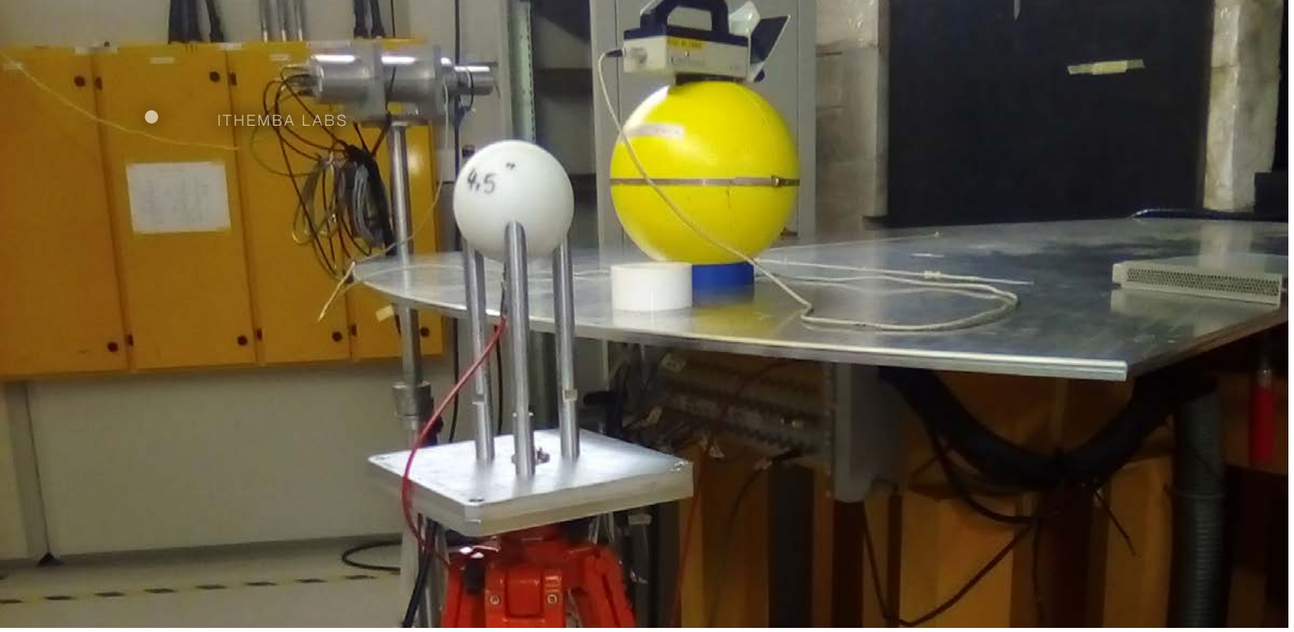
(Gamma-ray AsymMetric spectrometer for Knowledge in Africa) provides a unique array that combines detector elements from ALBA and AFRODITE. GAMKA was built by a consortium of iThemba LABS and several SA universities, and was supported by an NRF grant. In addition to the new frames, an investment was made in an on-site liquid nitrogen production plant capable of producing 260l/day. GAMKA is supported by the National Research Foundation of South Africa (Strategic Research Equipment Grant Number: 114668), and by contributions from iThemba LABS, Stellenbosch University, University of the Western Cape, University of the Witwatersrand and the University of Zululand.

K=600 magnetic spectrometer

The K=600 magnetic spectrometer is a high-resolution kinematically corrected magnetic spectrometer for light ions. It is capable of measuring inelastically scattered particles and reactions at extreme forward angles that include 0°, making it one of only two facilities worldwide (the other being at RCNP, Japan) where high-energy resolution is combined with 0° measurements at medium-beam energies. The advantage of such measurements is the selectivity it provides to excitations with low angular momentum transfer.

A new scattering chamber was designed and manufactured to accommodate the Coincidence Array for K=600 Experiments (CAKE). CAKE, shown on the left, consists of up to six wedge-shaped double-sided silicon strip detectors, placed in a lampshade configuration upstream from the target ladder. It enables coincidence spectroscopy of charged-particle decays following inelastic scattering and transfer reactions detected by the focal-plane detectors of the K=600.

Coincident γ-ray detection capability was recently added to the K=600 repertoire through the installation of a frame which allows for interchangeable configurations of up to 30 gamma-ray detectors, including AFRODITE-PLUS, ALBA and fast-timing detectors. The efficiency and granularity of the new set-up, and also the fact that K=600 measurements can be performed at zero degrees, all combine to make this set-up a unique experimental tool. Over the next years, a new focal-plane detector will be installed which will eliminate particles having to traverse air and will allow for the detection of heavier-mass particles or lower-excitation energies.



APPLIED STUDIES WITH THE SSC

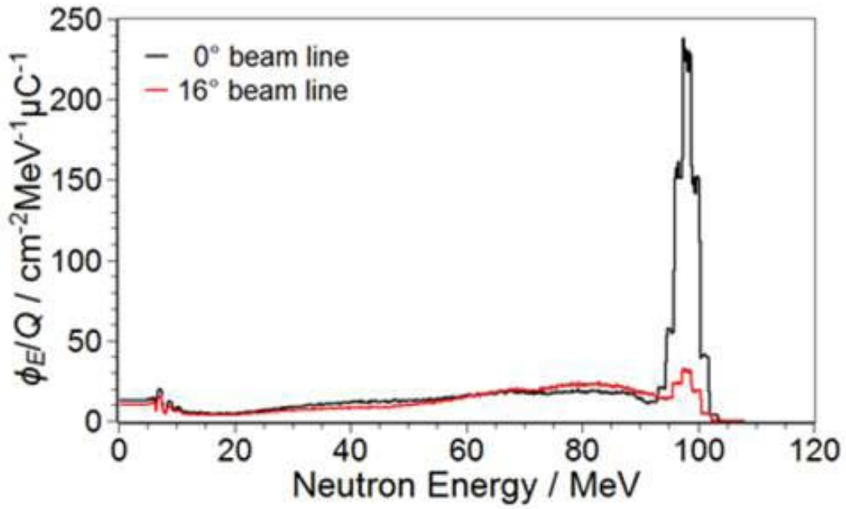
Fast neutron beam facility

One of the niche facilities at iThemba LABS is the availability of quasi-monoenergetic neutrons with energies between 30 and 200 MeV, which are typically produced by the 7Li(p,n)7Be or 9Be(p,n)9B reactions. The facility is capable of producing 200 MeV nanosecond-pulsed beams at high currents with a background-free interval between pulses. The time between beam pulses at 200 MeV is 33 ns, but can be increased to 230 ns by transmitting only one in seven pulses. An example of the neutron time-of-flight spectrum from 100 MeV protons on 7Li, measured at neutron emission angles of 0° and 16°, is shown on the right (EURADOS Report 2016-02, Irradiations at the High-Energy Neutron Facility at iThemba LABS). A collimator fan makes measurements possible for neutron emission angles of 0°, 4°, 8°, 12° and 16°. Carbon absorbers are used to remove charged particles contaminating the neutron beam. A quasi-monoenergetic neutron flux of 6,5 x 10^4 n cm^{-2} s^{-1} is obtained at 0° and 5 m downstream from the target by bombarding a 10 mm-thick Be target with 120 MeV protons.

The year 2020 saw the completion of the construction project in which the neutron facility was refurbished to meet the requirements for a high-energy neutron metrology facility. The refurbishment project included additional shielding, improved

beam diagnostic, optimized beam stops, a new target system and an extended flight path at 16°. The available flight paths now extend from 5 to 11 m at 0° and 5 to 13 m at 16°.

The ultimate goal is to achieve ISO accreditation, and for the vault to be recognised as a “medium- to high-energy” neutron beam reference facility.



An envisaged addition to the available infrastructure is the inclusion of a rapid transport system that will allow for the study of neutron-induced reaction products from (n,nx) and/or (n,f) reactions. The transport system known as RABBIT will relocate the irradiated targets from the high-neutron field environment to dedicated counting stations consisting of beta and gamma-ray counters. The project is delivered in partnership with the University of Cape Town.

Radiation biophysics

Radiation biophysics aims to better understand the biological effects of exposure to particle radiation types and energies and radiopharmaceutical compounds, and to serve the broader community by offering biodosimetry follow-ups to radiation

incidents nationally and internationally. iThemba LABS was one of the first facilities in the world to develop and operate a proton therapy facility. This resulted in a dedicated research programme focused on particle therapy through the availability of a beamline and biology laboratory. The expertise and infrastructure available are crucial in supporting the clinical research worldwide. The proton beamline has been relocated and substantially upgraded.

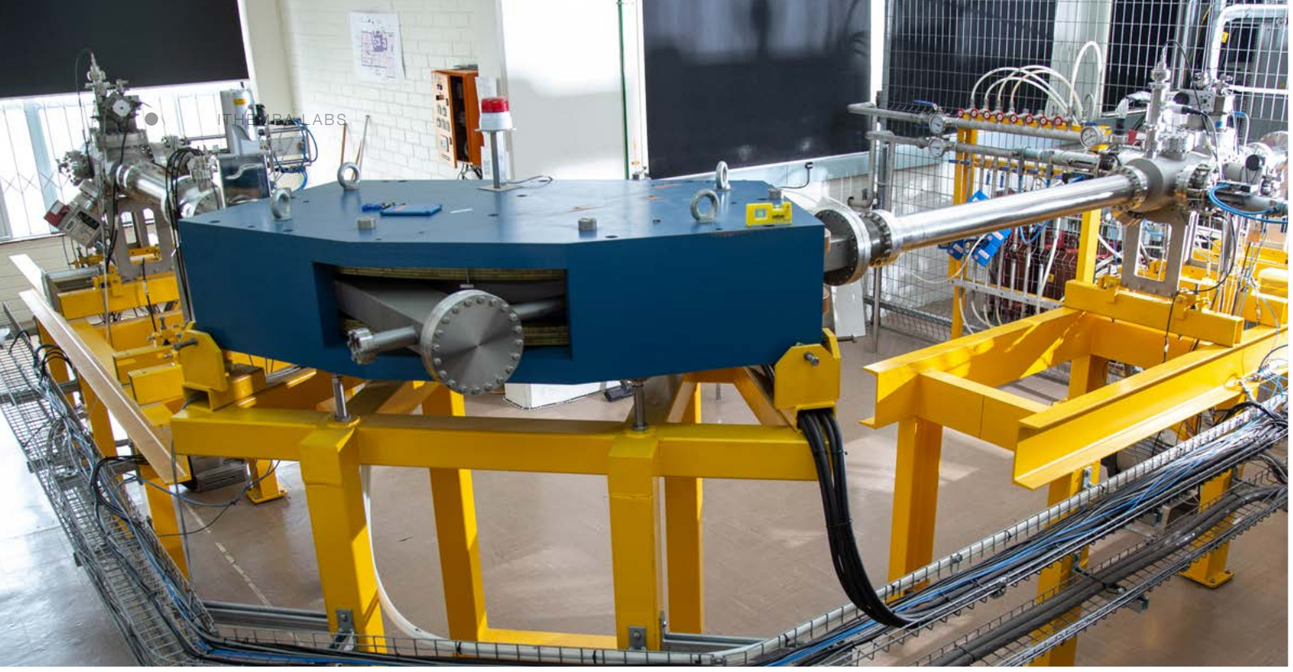
As a scientific and technological highlight, a commercial inhibitor for the membrane protein ADAM10, which is a potential target for cancer therapy, has been successfully radiolabelled at iThemba LABS, and a patent filing application was submitted in 2020.

It is known that elephants harbour 20 copies of the most powerful tumour-suppressor genes in humans. A research project is currently underway to collect skin and blood samples from elephants in the wild and in captivity. The samples are then irradiated using the particle beams at iThemba LABS and compared with similar samples from humans. It is hoped that this will lead to the discovery of alternative mechanisms for cancer suppression to facilitate the development of new drugs for the prevention and treatment of cancer.

The first experiments of the BELSPO/NRF collaboration have been conducted to establish a platform for the study of space health effects at an accelerator facility in Africa. There are currently large uncertainties linked to the biological effects of neutron irradiation and dose rate effects on astronauts. Preliminary results seem to suggest that neutron dose rates have an effect on the DNA repair and immune response of astronauts.

Isotope research and development

Alpha-particle-emitting radioisotopes have been the subject of considerable investigation as cancer therapeutics in recent years. In the context of targeted therapy, alpha-particle emitters have the advantage of high potency and specificity, a technique also referred to as Targeted Alpha Therapy (TAT). The European Cooperation in Science and Technology (COST) has set up an international clinical network dedicated to alpha therapy using 211At. The Network for Optimized Astatine labelled Radiopharmaceuticals (NOAR) aims to demonstrate that 211At is the most promising radionuclide for alpha therapy, thereby establishing it as the European standard for the treatment of certain cancer pathologies. 211At, has a half-life of 7,2 h, and is commonly produced through the 209Bi(α, 2n)211At production route using 29 MeV alpha beams. What is our focus and contribution to date?



SCIENCE WITH THE TANDEM ACCELERATOR

The Accelerator Mass Spectrometry (AMS) facility at iThemba LABS is the only AMS facility on the African continent and provides a platform for rare isotope measurements. The measurements of 14C, 26Al and 10Be are used in various contexts to determine the age of samples. The AMS facility, which was commissioned in 2017, has been providing a little more than 1 000 dates per year, a notable achievement in contrast to similar facilities sited elsewhere in the world. The impact of an AMS facility on palaeoscience in South Africa has been profound, as more dates allow for fundamentally better science to be conducted on the available data sets. The high-resolution dating of samples from Waterfall Bluff, and palaeoclimate records such as the baobab tree climate records, were just not possible before the AMS facility was commissioned. The result is that strategic platforms such as the African Origins Programme, which looks to exploit scientific advantages offered by South Africa as a location, are being substantially enhanced by this research facility.

Despite the restrictions due to the COVID-19 lockdown, over 850 samples were measured for 35 projects in cultural heritage, ecology and earth science. The results were presented in 27 articles, of which 16 have already been published. A total of

14 postgraduate students are making use of the AMS facilities, and nine MSc's have been successfully completed.

SCIENCE WITH THE TANDETRON ACCELERATOR

The Tandetron Laboratory consists of eight full-time researchers devoting their time to Ion-Beam Analysis (IBA), Nanoscience and Nanotechnology, X-ray Diffraction (XRD) and Atomic Force Microscopy (AFM). The lab conducts materials research for applications in information technology, electronics, air pollution, energy efficiency, water purification and thin film coatings. Stable particle beams from the 3-MV Tandetron accelerator are used for synthesis, modification and analysis of thin films and nanostructured materials. These particles are also used in quantitative and qualitative elemental analysis of various materials using ion-beam techniques such as Particle-Induced X-ray Emission (PIXE), Rutherford Backscattering Spectrometry (RBS) (real-time and normal) and Elastic Recoil Detection Analysis (ERDA). The specimens that are analysed include geological samples, archaeological samples, biological samples, and coatings from government institutions, academia and other research organizations.

The 3-MV Tandetron particle accelerator was installed and commissioned in May 2017 and has two multi-cusp sources for H- and He- ions with current thresholds of ~ 1mA before the low energy magnet, and ~ 200 µA post-acceleration. A Heavy Ion (HI) sputtering source is also included in the accelerator infrastructure, which creates many possibilities for ion-solid interaction research. In the basic ion-solid interaction research domain, measurements of fundamental parameters such as stopping force S(E), straggling and effective ranges for analysis are carried out on a routine basis.

The year 2020 saw a total of 26 postgraduate students offering research projects on the Tandetron and the complementary techniques, supervised by the research staff. The XRD facility had a total of 127 external users who regularly presented samples for analysis. The laboratory has a total of nine Memoranda of Agreement

with nine international collaborators and produced 12 articles in peer-reviewed journals during 2020/21.

The research laboratory has recently introduced a focus on laser-matter interaction using femtosecond laser, diffusion kinetic studies in nuclear and hydrogen storage materials, measurement of fundamental parameters in ion-matter interaction, and surface texturing or patterning using protons. It has also started to look into the expansion and development of new fields of applications of low-energy accelerators for societal benefit. Other programmes of the lab include a Coordinated Research Project (CRP) under the International Atomic Energy Agency (IAEA) programmes, i.e. Development and Application of Ion-Beam Techniques for Materials Irradiation and Characterization Relevant to Fusion Technology, and Transnational Access to Ion-Beam Accelerator of the Tandetron Laboratory at iThemba LABS.

HIGHLIGHTED RESEARCH PROJECTS

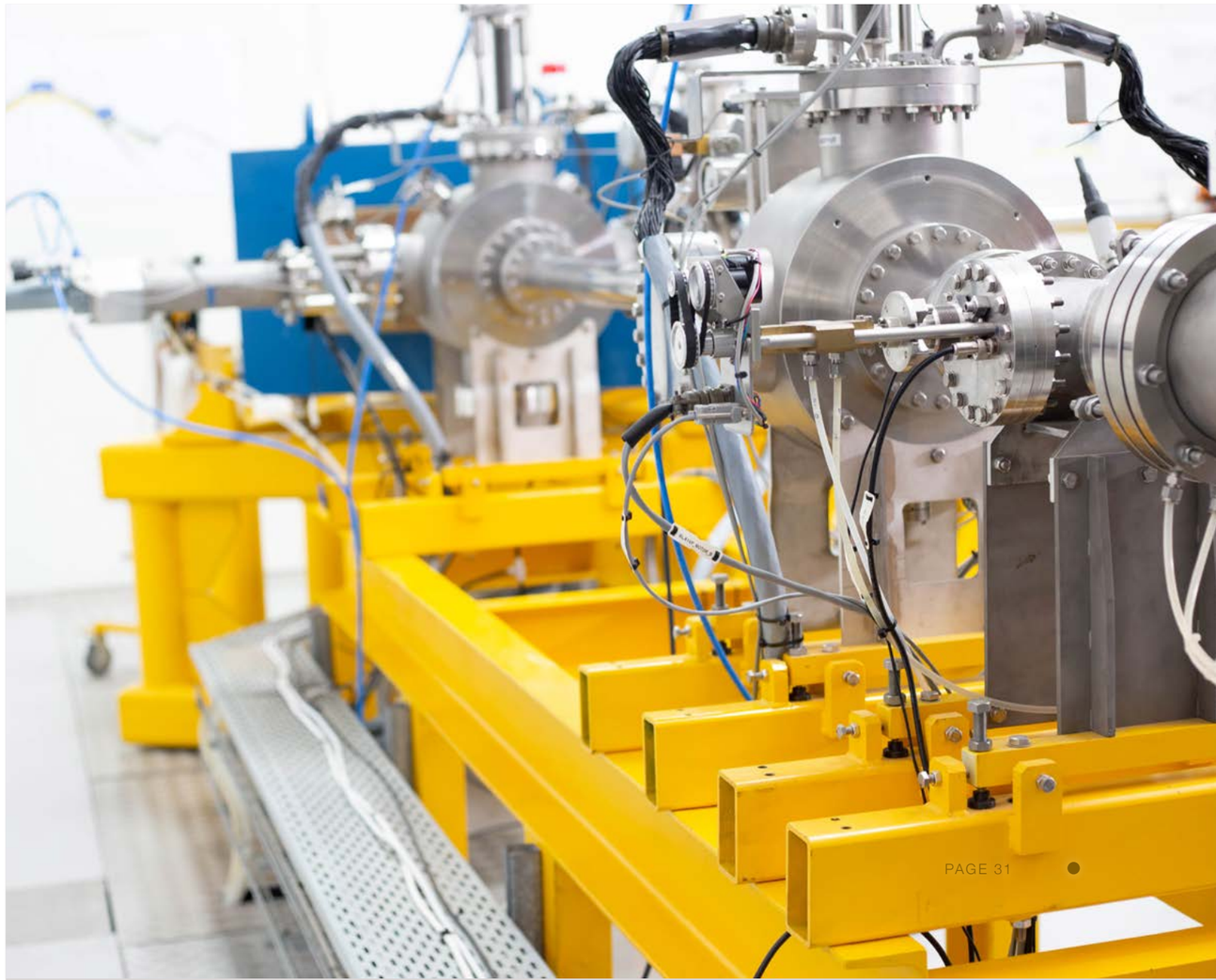
In-situ study of Pt reaction with oxygen-contaminated silicon layer

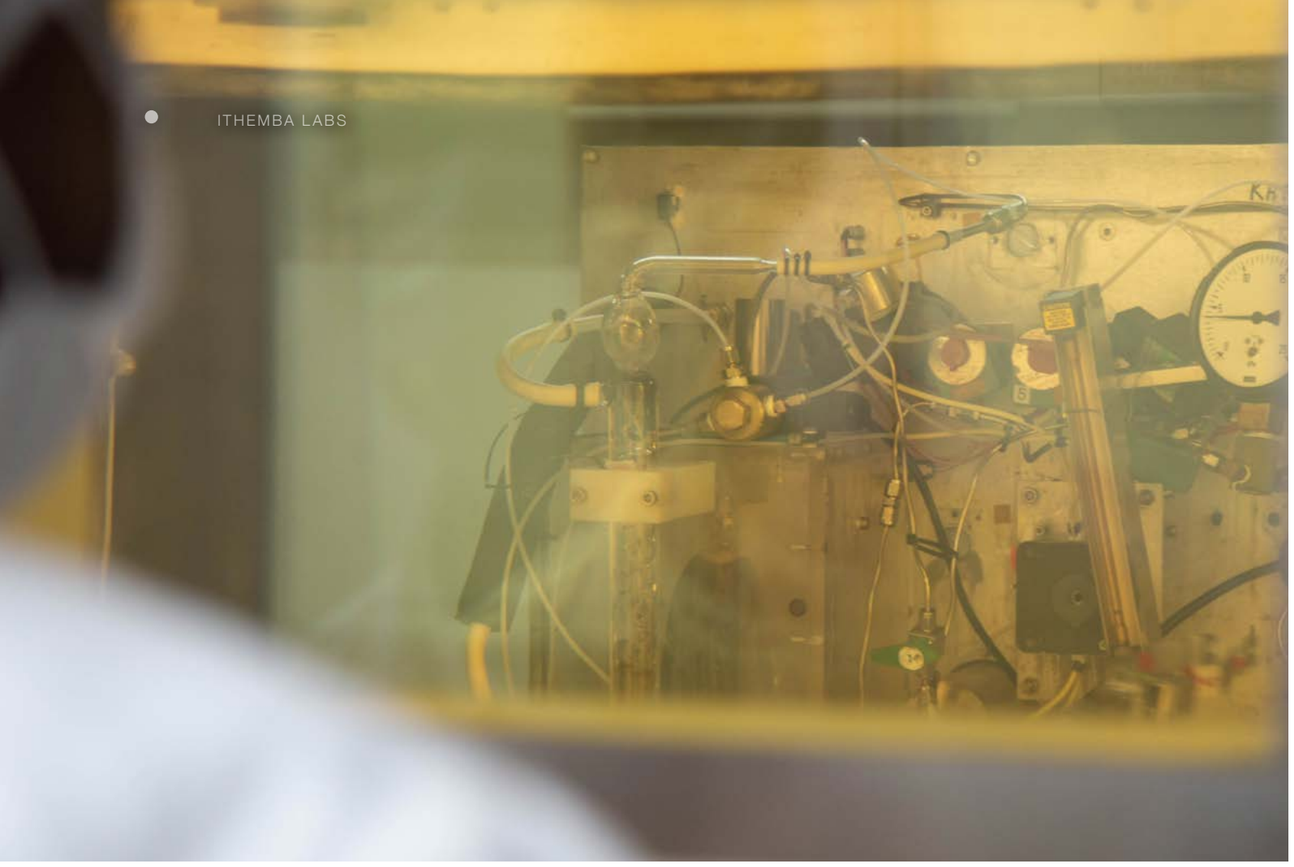
This work, which was published in the NIM B journal, reports on the study of the determination of the electrical properties of the core-shell SiNW-based devices. In this project, a simple step (annealing) was undertaken to eliminate the etching step, in order to fabricate contact structures in the core-shell SiNWs. A metal/SixOy contact structure was replicated by depositing the Si oxide layer, followed by a Pt layer. The main interest was to track the movement of O when the reaction starts. The results obtained in this study can be implemented in both n-type and p-type core-shell SiNW structures, depending on the intended application of the SiNW-based device.

Silver nanostructures embedding in polymethyl methacrylate patterns fabricated using proton beam writing

This study was aimed at testing the capability of the proton beam writing set-up at iThemba LABS to create patterns and exploit them for nanoparticle incorporation.

Square-like patterns were successfully achieved on PMMA, as was the incorporation of biosynthesized OR incorporating biosynthesized AgNPs to create composites. The composite forming method used in this study led to random and inside square cavities distribution of AgNPs. Scanning Electron Microscope (SEM) and Atomic Force Microscopy (AFM) were used as complementary techniques for imaging the fabricated patterns, and both revealed average widths and lengths of the squares measured as approximately 15 µm and 10 µm, respectively. The created patterns can be used as a mask for electroplating of metal electrode arrays for microstamp fabrication as well as microelectromechanical and nanoelectromechanical devices.





The development of multifunctional chamber for ion-beam analysis

iThemba LABS has expertise in the use of detector arrays, especially linked to the Separated Sector Cyclotron. The idea of “Total Ion-Beam Analysis” is a new idea that is being pursued by various laboratories similar to the Tandetron laboratory. The basic idea is to use multiple detectors to get maximum information from a single experiment. The current chamber that is used for solid state experiments does not support Total IBA, as it can accommodate only two fixed detectors. The group has embarked on a project to deliver a multifunctional chamber capable of establishing a vacuum of ~10^{7} mbar.

ENVIRONMENTAL RADIOISOTOPE LABORATORY

iThemba LABS is ideally positioned to make a meaningful contribution in the mining industry through the analysis of soil, plant, rock and water samples. Many of these analyses focus on the measurement of radon activity levels. Most African countries, including South Africa, are rich in mineral resources and have extensive

mining activities, and environmental radiation measurements are of significant importance. The study of radioactivity in environmental samples creates an opportunity for collaboration on the African continent. A total of 12 students are currently supervised, with three of these coming from countries OTHER than South Africa. A portable gamma-ray detection system equipped with a LaBr3:Ce detector has been designed and built in the form of a backpack that can be used for in situ measurement of radionuclide activity. Real-time activity data will be collected and synchronised with GPS coordination. Measurements will be done in designated areas relevant to the project. When measurements are done using the mobile system, grab samples (soil and water) will be taken and analysed in the laboratory using a gamma-ray spectrometer equipped with an HPGe detector. A comparison of in situ results obtained by the mobile device and those from the more sensitive laboratory spectrometer will allow the determination of the sensitivity, effectiveness and practicality of the mobile system.

SCIENCE ENGAGEMENT

The Science Engagement activities aim to raise awareness of the contribution that science makes to the improvement of people’s lives through effective communication and education. A dedicated area, the Visitor Centre, has been established in Cape Town to facilitate the interaction between iThemba LABS and the various groupings of the public. iThemba LABS also provides access to a computer laboratory to facilitate access to internationally based activities.

The International Masterclass creates an opportunity for high school learners to collaborate with particle physicists to analyze data from the Large Hadron Collider (LHC) at CERN, located near Geneva, Switzerland. A typical analysis would be based on data linked to elusive, unseen particles or would study a form of matter which existed shortly after the big bang. Through their interactions with their particle physics tutors, they are not only discovering fundamental particles, but also engaging with role models. The focus of the learning is an introduction to the scientific endeavour, which positions uncertainty as an essential component.

The Masterclass also incorporates the notion of collaboration by allowing the participants to interact with peers through an international video conference. The year 2020 allowed us to experiment with the possibility of offering the Masterclass not only at iThemba LABS, but also at the Nelson Mandela University in Port Elizabeth. This created an opportunity for two senior scientists from iThemba LABS, together with an MSc student from UCT and members of the ALICE Collaboration, to join forces with colleagues at the Physics Department of the Nelson Mandela University to host the event.

The Science Engagement team has been able to collaborate with the Physics Department at Stellenbosch University to introduce high school learners to environmental radioactivity. The engagement was facilitated by Prof. Richard Newman, who introduced the radon survey project. Learners and educators from various schools in the vicinity of iThemba LABS were given an electret ion chamber and asked to collect data by placing the chamber in their homes. The iThemba LABS computer laboratory was used for the analysis of the data.

The annual OPEN DAY provides an opportunity for members of the public to visit our facilities, as it normally coincides with the annual mid-year shutdown. Visitors are treated to guided tours of the facilities and allowed to interact with members of staff who man various information stations throughout the facility. In addition, a specialized programme is offered for our younger visitors. The theme of the 2019 OPEN DAY was “Come and see how atoms add value to life”.

Public lectures are used as a vehicle to keep members of the public informed and to build a scientifically literate society. iThemba LABS, through the Science

Engagement team, has offered a number of public lectures that have included speakers from across the National System of Innovation. The following were hosted during the period under review:

- Dr Stephan Woodbourne (iTL) on Climate Change and its implications for the southern African regions
- Professor Leslie Petrik (UWC) on Environmental Science and Nanoscience
- Dr Hlumani Ndlovu (UCT) on Biological Sciences
- Professor Richard Walls (SU) on Fire and Safety in Informal Settlements
- Motivational talks by female members of staff in celebrating Women’s Day

The Science Engagement team understands the need to maintain the pipeline that feeds the National System of Innovation. It has, to this end, prioritized interventions that support the learning and teaching of science in primary and secondary schools. It will also be prioritizing interventions to establish a visual presence of active scientists in schools through non-specialist talks and motivational sessions.

Image (below): Learners participating in an interactive workshop on electric circuits.

HCD
HUMAN CAPACITY DEVELOPMENT

Investment in (formalized) staff development

Name	Qualification	Institution	Position	Date
Ambrose Yaga	Web Design	UCT	Manager: Science Advancement and Comm	2019
Donovan Wyngaard	BA: Psychology	UNISA	Design Project Manager	2019
Ntombi Kheswa	PhD : Physical Science	SU	Research Scientist	2019
Aurelia Genu	Msc: Physics	UNISA	Radiation Protection Physicist	2019
Peter Du Plessis	MSc: Radiography : Therapy	CPUT	Radiographer	2019
Sameul Selinyane	Fiiting and Turning	Thandabantu Skills Training centre	Workshop Assistant/ Driver	2019
Hamilton Shipalana	Fiiting and Turning	Thandabantu Skills Training centre	Workshop Assistant	2019
Luyolo Sabsana	Btech: Business Administration	CPUT	Supply Chain Management Practitioner	2020
Cezar Thenjwayo	Btech: Mechanical Engineering	CPUT	Mechanical Technician	2020
Anathi Gama	Higher Certificate in Archives and Records Management	UNISA	Housekeeper	2020
Abie Kwellilanga	Bachelor of Science Honours -Physics	UNISA	Snr Research Analyst/ Radiation PO	2021
Joshua Lewis	Advanced Diploma Information and Resource Management	UNISA	IT Systems Administrator	2021

Number of students who graduated in 2019, 2020 (and 2021)

Name	Degree	Affiliation	Laboratory	Date
Lerato Baloyi	MSc	WITS	SSC	2019
Adolf Motetshwane	MSc	BIUST	SSC	2019
Lance Davis	MSc	UWC	SSC	2019
Sizwe Mhlongo	MSc	Unizulu	SSC	2019
Tarryn Bailey	MSc	SU	SSC	2019
Papie Mojaki	MSc	NWU	SSC	2019
Sinegugu Mthembu	MSc	Unizulu	SSC	2019
Hendric Pogiso Moabi	MSc	NWU	TAMS	2019
Lehlohonolo Lisema	MSc	WITS	TAMS	2019
Kgashane Malatji	PhD	SU	SSC	2019
Christiaan Brits	PhD	SU	SSC	2019
Chane Moodely	PhD	WITS	SSC	2019
Estelle Razanatsoa	PhD	UCT	TAMS	2019
Thulani Chriswell Dlamini	PhD	NWU	SSC	2019

Name	Degree	Affiliation	Laboratory	Date
Boitumelo Makabachaba	MSc	UWC	Tandetron	2020
Avuyile Bulala	MSc	UCT	SSC	2020
Rivoningo Ripanzell Khosa	MSc	UJ	TAMS	2020
Tamryn Hamilton	MSc	WITS	TAMS	2020
Tamara Botha	MSc	WITS	TAMS	2020
Refilwe Setso	MSc	WITS	SSC	2020
Nathan Boyles	MSc	UCT	SSC	2020
Christine Marie Monteverdi	MSc	UCT	SSC	2020
Hamza Mohamed	PhD	UNISA	Tandetron	2020
Doris Jiosta	PhD	SU	SSC	2020
Mistura Ajani	PhD	WITS	SSC	2020
Skye Segal	PhD	UCT	SSC	2020
Sibaliso Mhlanga	PhD	UCT	SSC	2020
Sunday Daniel Olorunfunmi	PhD	WITS	SSC	2020
Abraham Avaa	PhD	WITS	SSC	2020
Olakunle Oluwaleye	PhD	UNISA	TAMS	2020
Gharib Mohamed	PhD	UWC	SSC	2020
Floyd Mabiala	MSc	UWC	Tandetron	2021
Jadvy Kouka	MSc	UWC	Tandetron	2021
Jean Baverstock	MSc	UKZN	TAMS	2021
Veronica Gouws	MSc	NWU	TAMS	2021
Sfundo Khanyile	PhD	UNISA	Tandetron	2021
Makhangela Mbambo	PhD	UNISA	Tandetron	2021
Pierre Kibasomba	PhD	UNISA	Tandetron	2021
Armand Bahini	PhD	WITS	SSC	2021
Lucky Makhathini	PhD	SU	SSC	2021
Mistura Ajani	PhD	WITS	SSC	2021
Amour Khamis	PhD	University of Dar Es Salaam	SSC	2021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