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South African Isotope Facility

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The iThemba Laboratory for Accelerator Based Sciences is based around a K=200 Separated Sector Cyclotron (SSC), which is used for nuclear physics research, radionuclide production, and hadron therapy. It plans in future to build an ISOL radioactive-ion beam facility. Protons will be used for the direct fission of Uranium, to produce fission fragment beams.

A high-current, 70 MeV cyclotron will be acquired to take radionuclide production off the SSC. A freed up SSC will then be available for an increased tempo of nuclear physics research.

The project has begun with a RIB "test facility", now under construction. In a collaboration with INFN Legnaro, the target/ion-source "front-end" will be a copy of the front-end developed for the SPES project. A variety of targets may be inserted into the SPES front-end; a uranium-carbide target has been designed to produce up to 2×10^{13} fission/s using a 70 MeV proton beam of 150 μA intensity. It is expected that intense fission fragment beams will become available for low-energy nuclear physics experiments after 2018.

The next phase will see the beams post-accelerated. At this stage, a number of options are being considered including a LINAC.

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1. Introduction

The iThemba Laboratory for Accelerator Based Sciences (iThemba LABS) is a Facility within the National Research Foundation (NRF) of South Africa. It is the premier atomic particle accelerator laboratory on the African continent and the only facility of its kind in the southern hemisphere. The research agenda of the facility is based primarily on the 30 year old Separated Sector Cyclotron (SSC), an accelerator which produces particle beams for research, for the production of radioisotopes, and for hadron (proton and neutron) therapy. The iThemba LABS radioactive-ion beam (RIB) project, based on the fission of uranium and the Isotope Separation OnLine (ISOL) technique has been under devclopment for some time. The latest developments of the project are presented here.

1.1 Activities and Mode of Operation

iThemba LABS is a multiuser facility – the three disciplines of nuclear physics research, radioisotope production and hadron therapy share the SSC according to a weekly schedule.

1.1.1 Nuclear Physics

Nuclear physics research is centered around two main instruments – a *k=600* light-ion spectrometer and the AFRican Omnipurpose Detector for Innovative Techniques and Experiments (AFRODITE)[1]. AFRODITE is presently equipped with nine Compton-suppressed “clover” detectors and 8 Low-Energy Photon Spectrometers (LEPS), used for in-beam γ-ray spectroscopy. The array will be upgraded during 2017 with an additional three Compton-suppressed clovers; a funding application for four more clovers has been submitted. When fully equipped, the array is expected to have a total efficiency of over 3% at 1.3 MeV. Some of the recent successes of the array embrace new insights into the nature of nuclear chirality [2,3]. Following a recent upgrade to allow the operation of the “K600” spectrometer at zero degrees[4], further improvements include the addition of “CAKE” (a Co-incidence Array for K600 Experiments), comprising four MMM-400 double sided silicon strip detectors in a lampshade configuration of 16 rings and 8 sectors. It is presently being used to search, for example, for Hoyle-like states in ^{16}O. The next development will see clovers from the AFRODITE array combined with the K600 spectrometer to study the pygmy dipole resonance via inelastic α-scattering on ^{154}Sm.

1.1.2 Radioisotope Production

iThemba LABS uses a 66 MeV proton beam of up to 250 μA current to produce radio-pharmaceuticals for over 25 Nuclear Medicine departments at private and public healthcare facilities throughout Southern Africa. Longer-lived radionuclides are also produced for the export market to assist in cost recovery. They are despatched to over 40 clients worldwide and include ^{82}Sr/^{82}Rb generators and radionuclides such as ^{68}Ge and ^{22}Na.

1.1.3 Constraints

Due to the multidisciplinary nature of iThemba LABS, nuclear physics research is however, limited to weekends, and cannot sustain an experimental programme requiring extensive, continuous beam time. For example, the production of RIBs, while technically possible using the SSC as a driver accelerator, would not be viable for an experimental programme unless the SSC could be dedicated to the task for a continuous period of several weeks. Therefore, to have an internationally competitive research programme, a priority is the removal of hadron therapy and radioisotope production away from the SSC. Hadron therapy would ideally be located at a hospital, while a new accelerator should be acquired for radioisotope production. With the acquisition of a second accelerator, RIB production using the ISOL method would become viable and allow, for example the study of neutron-rich nuclei along the *r*-process path.

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The NRF has funded both a technical design study into the production of RIBs and the construction of an ISOL test facility at iThemba LABS. The proposal centers around the addition of an off-the-shelf, commercially-available 70 MeV cyclotron such as those made by Best Cyclotron Systems Inc. (BCSI) [5] or by Ion Beam Applications (IBA) [6]. These machines are highly compatible with radioisotope production, offering high current beams of up to 700 μA at 70 MeV. One of the conclusions of the technical design study is that a completely green-field facility for the new cyclotron would be both cost and time prohibitive. Instead, the study recommended the concept now known as the South African Isotope Facility (SAIF). It comprises two phases, the Accelerator Centre for Exotic Isotopes (ACE Isotopes) and Accelerator Centre for Exotic Beams (ACE Beams).

The Ace Isotopes project would see the installation of the 70 MeV cyclotron in a vault presently used for neutron therapy, while the existing proton therapy vault and a spare vault would be used to house the bombardment stations for radioisotope production, see Figure 1. In this way, radioisotope production would be completely decoupled from the SSC.

ACE beams would see the production of post-accelerated RIBs. The RIB test facility, presently under construction, would be upgraded to become the Low-Energy RIB facility (LERIB), the main ISOL bombardment target/ion-source for ACE Beams. LERIB represents a collaboration between iThemba LABS and INFN Legnaro – the “front-end” or target/ion-source is identical to that of the SPES project [7]. As part of this collaboration, a high-power test of a SiC target has been successfully conducted [8]. The test confirmed the ability of FEM calculations to simulate temperature and stress profiles

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of the production target under realistic conditions. A UC_x target and the use of a 150 μA, 66 MeV proton beam from the SSC at iThemba LABS would see the fission rate increase to 2×10^{13} fissions per second. Because LERIB will use the SSC as the driver accelerator, the construction of a new post-accelerator will be necessary. ACE Beams will include the beam-cooling, high-resolution mass-separation and charge breeding necessary prior to post-acceleration.

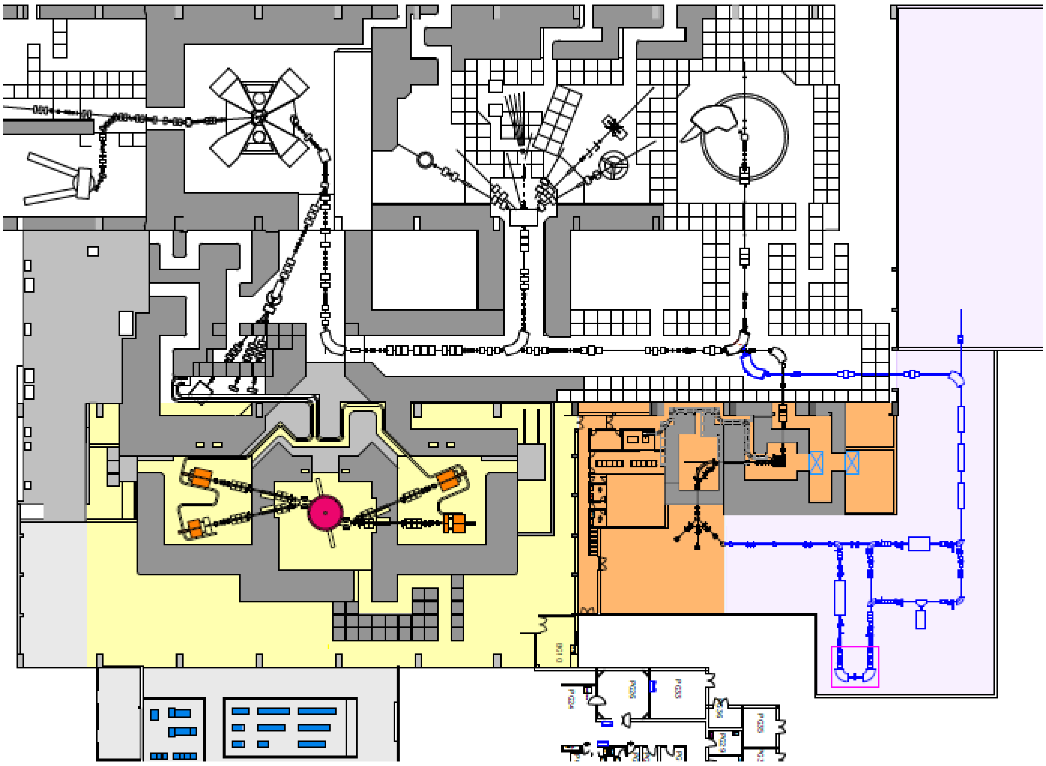

Figure 1. The ACE Isotopes project would see the existing therapy vaults converted into a radioisotope production facility, housing a 70 MeV cyclotron and new radioisotope bombardment stations (yellow). The SSC (top left) would be used to provide a 66 MeV proton beam to the LERIB facility (orange) which will eventually supply low-energy RIBs for post-acceleration in the ACE Beams facility (purple).

The first beams from the LERIB facility are expected to become available for physics experiments from late 2018 or early 2019. Beta-decay tape stations are presently under construction and will be equipped with clover detectors from the AFRODITE array, LaBr3(Ce) detectors for fast timing and an electron spectrometer for conversion electron spectroscopy.

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