Recent Developments and Proposed Applications with the Accelerators at iThemba LABS

Cape Town – “Mother City”

Officially founded on 6 April 1652
Accelerators at iThemba LABS

- K8 Injector Cyclotron 2
- K200 Separated Sector Cyclotron
- K8 Injector Cyclotron 1
- 6 MV EN Tandem AMS
- 3 MV Tandetron
- 6 MV EN Tandem AMS
- K11 Cyclotron - FDG PET Isotopes
Outline of the Talk

• New tandemron accelerator and applications
• AMS applications with 6 MV tandem accelerator
• Proposed new isotope production facilities
• New radioactive ion beam facility
Replacement of the 52 years old Van de Graaff
New tandetron accelerator installed

- Commissioned in May 2017.
- With 6 MeV proton delivered from multicusp ion source with 200 µA current
- With Multicusp source for He-ions production
- With Cesium sputtering source for heavy ions, tested with Si-ions
ION-BEAM INTERACTION AND SURFACE CHARACTERIZATION OF MATERIALS BY ION BEAMS
Materials Research Department (MRD)

CN 6 MV Van de Graaff accelerator

- Purchase Order 1961
- Tested at HV, USA: August 1963
- Infrastructure for VDG completed on August 1963
- Delivered at Cape Town Harbour 17 September 1963
- Operating since end 1963
- Officially opened May 1964
- Total Operating hours: 250 000 - 300 000
- One of the few CN 5.5 MV VDG digitally operated

The FUTURE:
- Low energy nuclear reactions for Astrophysics
- Characterization of nano-structures materials with nanometer ion beams sizes
- Ion Beam Analysis: *in-situ* RBS, Cryo-NMP, HI_ToF_ERDA, HE-PIXE
- IBA in tandem with e-beam deposition
- External beam for Archeometry and materials sciences
- Ion implantation, radiation hardness
- Environment sciences

The past 50-years:
- Low energy nuclear physics
- Nuclear analytical chemistry
- Ion Beam Analysis (RBS, NMP)
AMS Department, based at University of the Witwatersrand Accelerator Mass Spectrometry (AMS) Facility unveiled in 2014.

- $^{14}$C dating: 60,000 years
- Other isotopes ($^{10}$Be, $^{36}$Cl, $^{26}$Al): 1 – 10 My

6 MV Tandem (Gauteng): Previously Schonland Research Centre of the University of the Witwatersrand Extensively refurbished and fitted with an Ion Source for Accelerator Mass Spectrometry.
SNICS Ion Source
High-energy extraction
“Support the country's universities to produce a critical mass of palaeoscience researchers with a range of research, technical, curatorial, public engagement and managerial skills and drive knowledge production and exploitation to make South Africa a world centre of scientific excellence in the palaeosciences”
Cosmogenic dating in South Africa

Burial Dating

Australopethicus sediba
Malapa
1.95 - 1.78 Ma
(Dirks et al. 2003)

Stw 573 – “Littlefoot”
Sterkfontein
4.02 Ma
(Partridge et al. 2003)
iThemba AMS-based Research

[Map of Southern Africa with research sites indicated]

[Image of a baobab tree]

[Graph showing δ¹³C values over time (1000 to 2000 CE), with wet and dry periods indicated]

δ¹³C
11 MeV Cyclotron for PET isotope production
Separated-Sector Cyclotron Facility

- Polarized ion source
- SSC
- Target vaults
- Spectrometer
- SPC1
- SPC2
- ECR ion source
- Radioisotope production
- Proton therapy
- Neutron therapy
- Electronics
- Beam swinger

Dimensions: 960.0x540.0
4.4 MVA Uninterruptible Power Supply
New Battery Bank for the UPS
New Digital Low Level RF Control System

- Modular Design
- Digitally programmable
- 16 bit Amplitude resolution
- Operates between 5 and 100 MHz
- Programmable in steps of 1 µHz
- Phase resolution in steps of 0.0001º
- EPICS based
Complete Solution

iThemba LABS & Beckhoff

RF Control

Power amplifier, anode, grid, trimmer, coupling capacitor and short circuit plate control
Increase beam intensity (66 MeV protons) for isotope production
<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half-Life (days/years)</th>
<th>Nuclear Reaction</th>
<th>Product</th>
<th>Main Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{82}\text{Sr}$</td>
<td>25 days</td>
<td>$\text{Rb}(p,xn)^{82}\text{Sr}$</td>
<td>Produced as a radionuclide</td>
<td>Used to manufacture $^{82}\text{Sr}/^{82}\text{Rb}$ generators</td>
</tr>
<tr>
<td>$^{68}\text{Ge}$</td>
<td>271 days</td>
<td>$\text{Ga}(p,xn)^{68}\text{Ge}$</td>
<td>Produced as a radionuclide</td>
<td>Used to manufacture $^{68}\text{Ge}/^{68}\text{Ga}$ generators or used for calibration of gamma camera’s or PET CT scanners</td>
</tr>
<tr>
<td>$^{88}\text{Y}$</td>
<td>106.6 days</td>
<td>$\text{Sr}(p,xn)^{88}\text{Y}$</td>
<td>Produced as a radionuclide</td>
<td>Non–medical application</td>
</tr>
<tr>
<td>$^{109}\text{Cd}$</td>
<td>453 days</td>
<td>$\text{Ag}(p,xn)^{109}\text{Cd}$</td>
<td>Produced as a radionuclide</td>
<td>Non-medical application</td>
</tr>
<tr>
<td>$^{22}\text{Na}$</td>
<td>2.602 years</td>
<td>$\text{Mg}(p,n)^{22}\text{Na}$</td>
<td>Produced as a radionuclide</td>
<td>Positron Annihilation Studies</td>
</tr>
</tbody>
</table>
## Current Radiopharmaceuticals in routine production

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half-Life (hours)</th>
<th>Nuclear Reaction</th>
<th>Radiopharmaceutical Product</th>
<th>Main Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{18}$F</td>
<td>1.83</td>
<td>$^{15}$O(p,n)$^{18}$F</td>
<td>$^{18}$F-FDG</td>
<td>Glucose metabolic studies</td>
</tr>
<tr>
<td>$^{67}$Ga</td>
<td>78.3</td>
<td>Zn(p,xn)$^{67}$Ga Ge(p,x)$^{67}$Ga</td>
<td>$^{67}$Ga-citrate</td>
<td>Localization of certain tumours and inflammatory regions</td>
</tr>
<tr>
<td>$^{81}$Rb/$^{81}$mKr</td>
<td>4.58</td>
<td>Kr(p,xn)$^{81}$Rb</td>
<td>$^{81}$Rb/$^{81}$mKr generator</td>
<td>Lung ventilation studies</td>
</tr>
<tr>
<td>$^{123}$I</td>
<td>13.2</td>
<td>$^{127}$I(p,5n)$^{123}$Xe $\rightarrow$ $^{123}$I</td>
<td>$^{123}$I-sodium iodide $^{123}$I-mIBG</td>
<td>Thyroid studies Localization of certain tumours such as neuroblastoma, pheochromocytoma</td>
</tr>
</tbody>
</table>
New Isotope Production Facilities for iThemba LABS
ACE ISOTOPES
ANS Conference
13th International Topical Meeting on Nuclear Applications of Accelerators
Hilton, Quebec, Quebec City, Quebec, Canada
31 July – 4 August 2017
Beam test on 50kW INFN target

**Vacuum:**

- 500µA
- $6 \times 10^{-8}$ Torr
Beam line losses

Beam losses measured at various current.

\[
\text{Beam losses} = \frac{\text{Unaccounted Beam currents}}{\text{Extracted Beam currents}} \times 100\%
\]

Unaccounted currents have been measured as the difference between extractor probe current and sum of all beam line currents (slits, baffles and target currents).

<table>
<thead>
<tr>
<th>Beam current on target</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 µA</td>
<td>0.2%</td>
</tr>
<tr>
<td>400 µA</td>
<td>0.5%</td>
</tr>
<tr>
<td>500 µA</td>
<td>0.5%</td>
</tr>
</tbody>
</table>
Low Energy Rare Isotope Beam Facilities at iThemba LABS
Front End assembly as installed in the RIB off-line test facility at iThemba LABS
The SPES target (chamber lid removed), designed for a 40 MeV proton beam entering from the right. The heating current flows through the Ta tube, between the copper clamping bars at each end. The small central tube connects the target chamber to the ion source. [Andrighetto 2011]

CAD drawing of the SPES target assembly, showing the UC₅ disks (yellow) in a graphite tube and also the beam dump disks (dark grey). [SPES 2010]
Expected yields of singly-charged radioactive ions from the LERIB target-ion-source, when a UC\textsubscript{x} target is bombarded by 50µA of 70 MeV protons

Nuclear Landscape

- Intensity (ions/sec)
- Z (proton number)
- N (neutron number)

- Naturally occurring nuclei
- Radioactive nuclei
- Unknown nuclei
Thank You