Research at iThemba LABS: Present and Future

iThemba Laboratory for Accelerator Based Sciences

- **a multi disciplinary research centre,**
- **operated by the NRF (National Research Foundation**
- **Research and training in the physical, biomedical and material sciences**
- **Production of radioisotopes and radiopharmaceuticals**

science & technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

Kobus Lawrie

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NRF National Research Foundation
iThemba LABS Laboratory for Accelerator Based Sciences

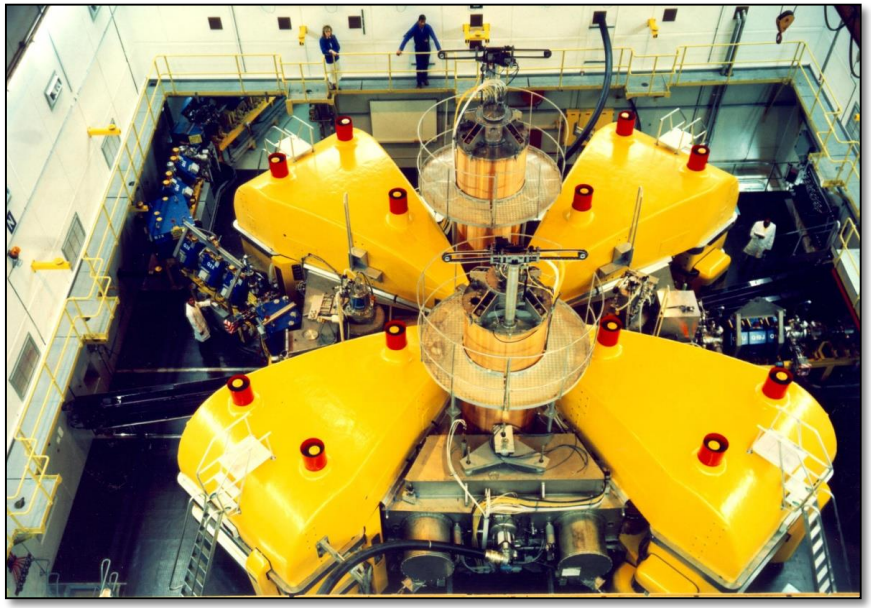

ZIMBABWE
MOÇAMBIQUE
NAMIBIA
BOTSWANA
Johannesburg
iThemba LABS (Gauteng)
6 MV EN
Tandem
Ion Implanter
SWAZI-LAND
LESOTHO
Durban
SOUTH AFRICA
iThemba LABS
Cape Town
Port Elizabeth

Accelerators at iThemba LABS

K8 Injector cyclotron 1
p, d, α
High current

K8 Injector cyclotron 2
p, d, α
Heavy Ions
Polarized p

K200 Separated sector cyclotron



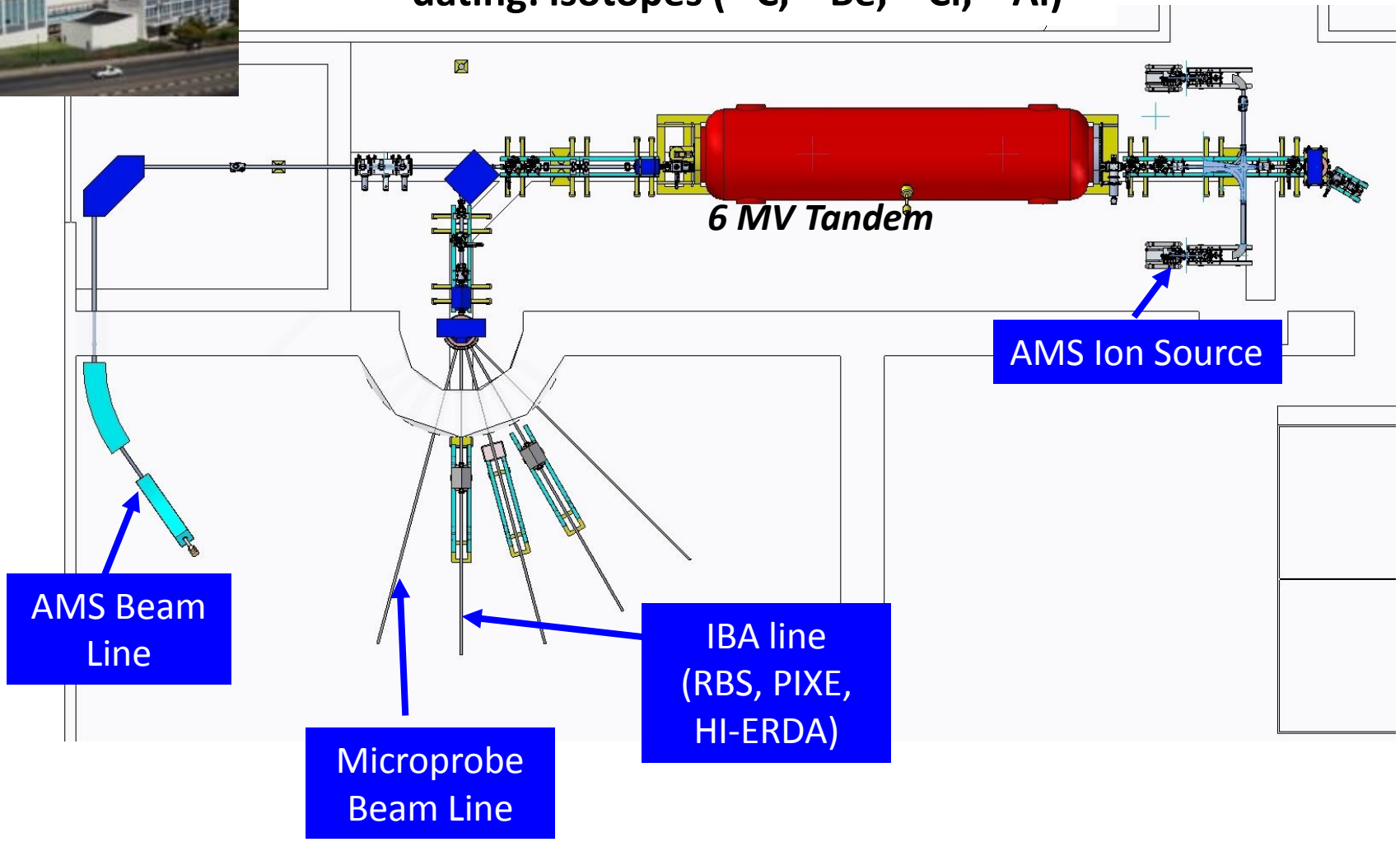
K11 Cyclotron
11 MeV p

3 MV Tandetron

6 MV Tandem

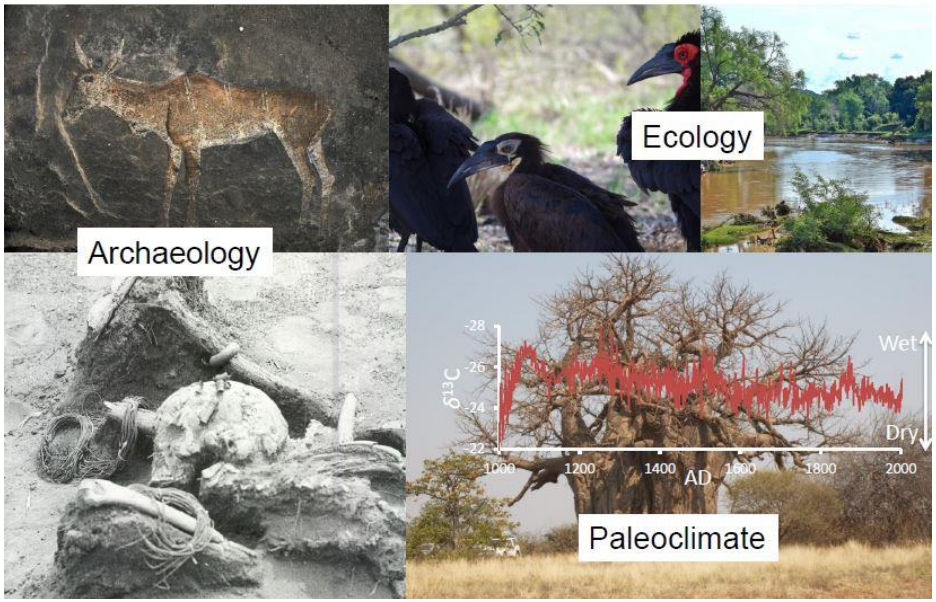
Tandem and Accelerator Mass Spectrometry Department

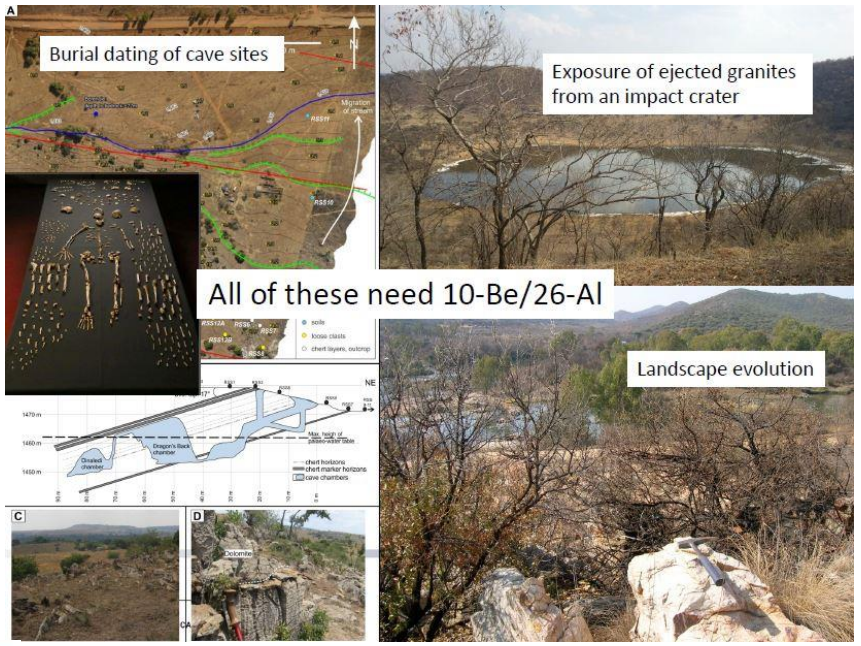
dating: isotopes (^{14}C, ^{10}Be, ^{36}Cl, ^{26}Al)



AMS Applications

Radiocarbon Applications





nature plants

BRIEF COMMUNICATION

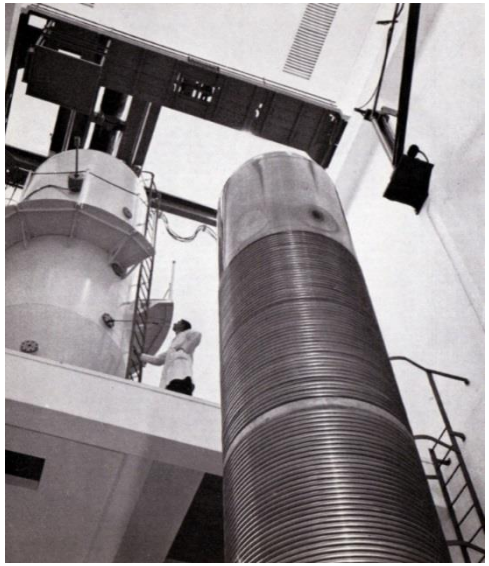
https://doi.org/10.1038/s41477-018-0170-5

The demise of the largest and oldest African baobabs

Adrian Patrut[1*], Stephan Woodborne[2], Roxana T. Patrut[3], Laszlo Rakosy[3], Daniel A. Lowy[4], Grant Hall[5] and Karl F. von Reden[6]

"We report that 9 of the 13 oldest and 5 of the 6 largest individuals have died, or at least their oldest parts/stems have collapsed and died, over the past 12 years;"

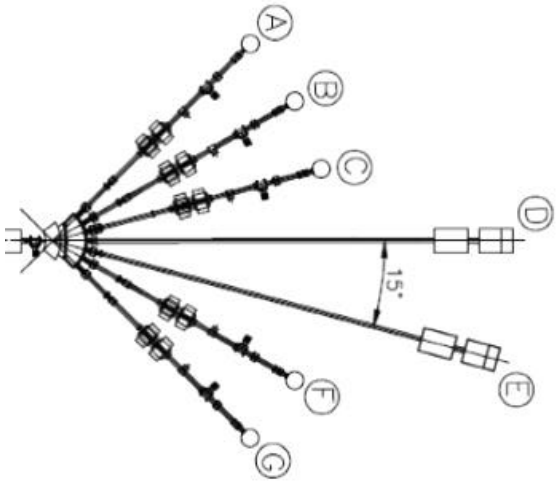
2017 : Replacement of the 52 years old Van de Graaff with a 3 MV Tandetron accelerator

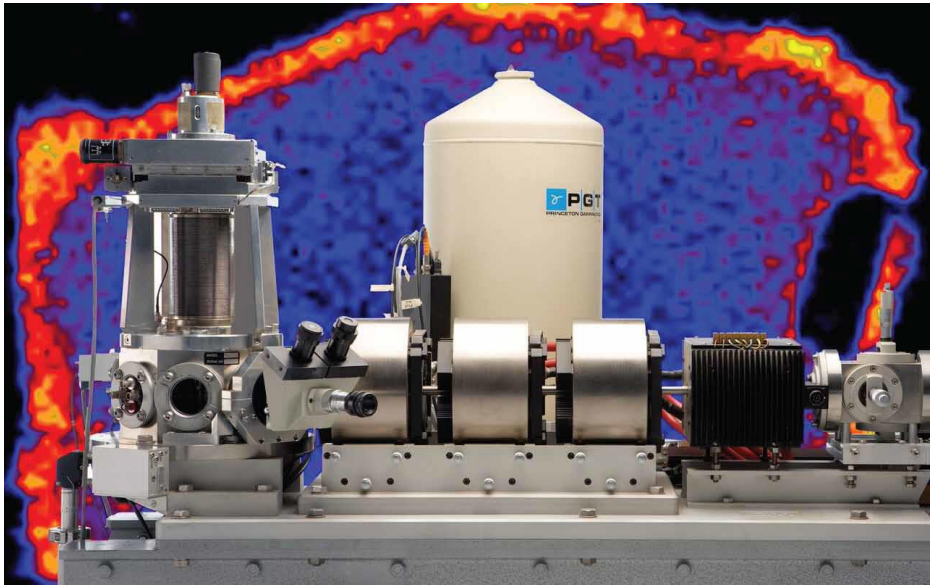


6MV VdG

3MV Tandetron
Ion sources for p, α, HI

μ Probe
and RBS
Beam lines

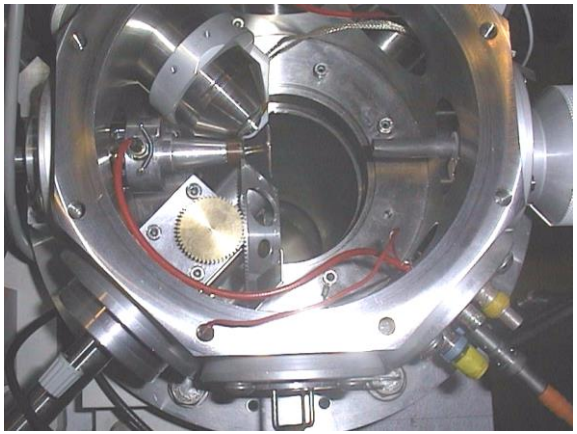




Micro PIXE

Proton beam writing

Nano - devices characterization



Features:

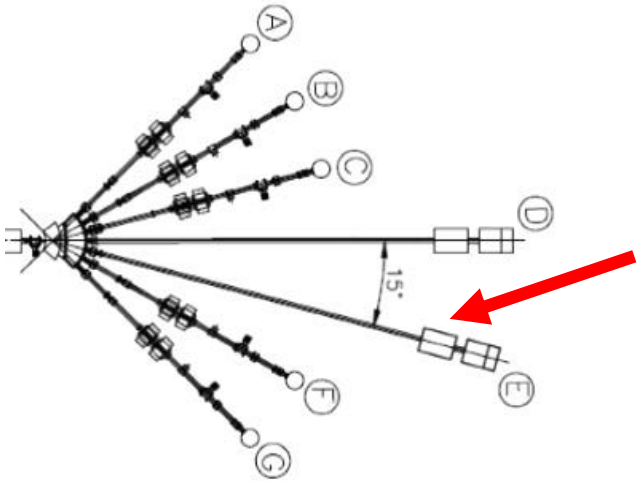
Oxford Microbeams)
Best beam spot at 100 pA
X – 1.6 μm ; Y – 0.6 μm

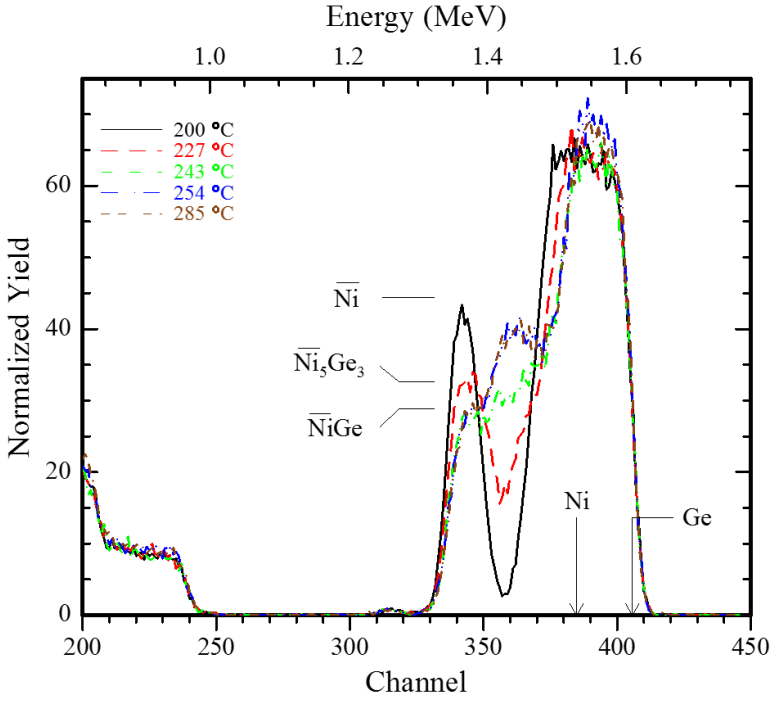
Typical sizes: X – 3 μm ; Y – 3 μm

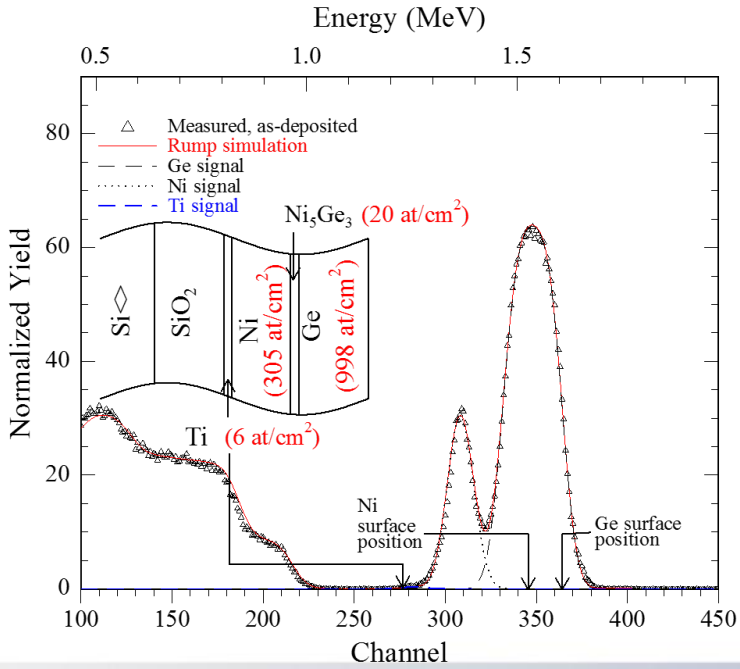
Projected for tandetron (300 -400 μm)

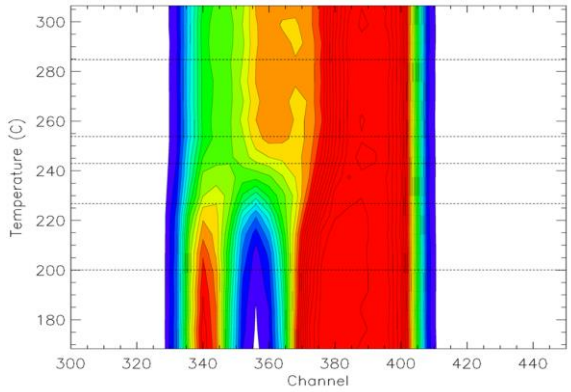
Chamber with stepper motors
for automated specimen movement;
Permanently mounted set of standards:
44 pure metals, 53 minerals, fused glasses

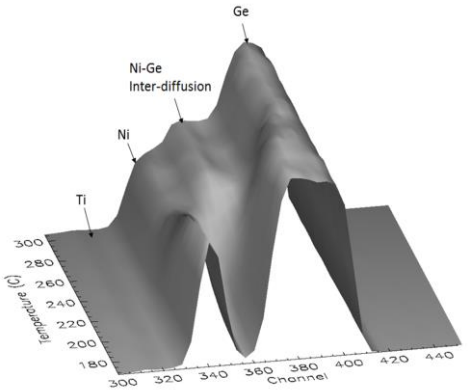
RBS-ERDA-CHANNELING



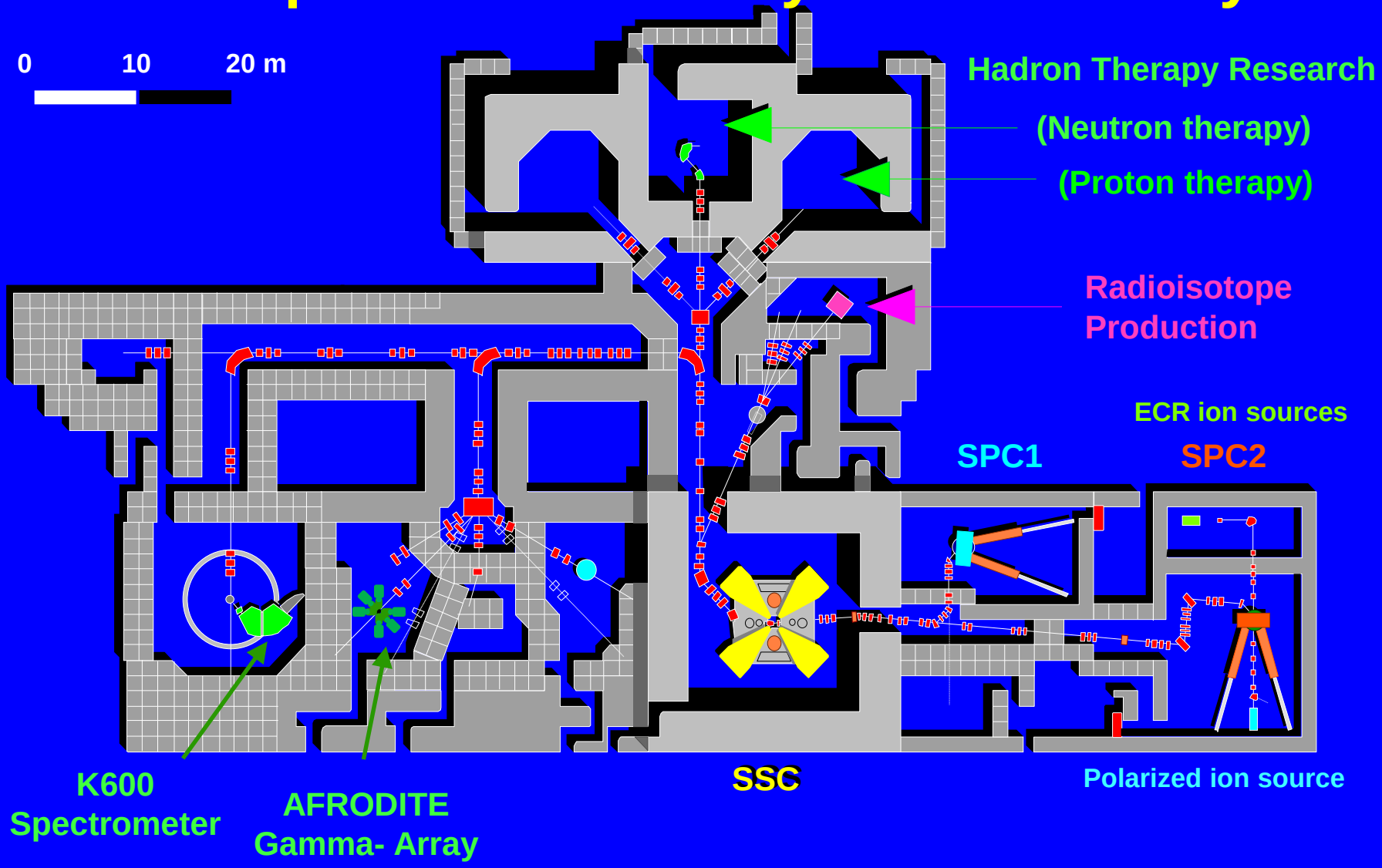




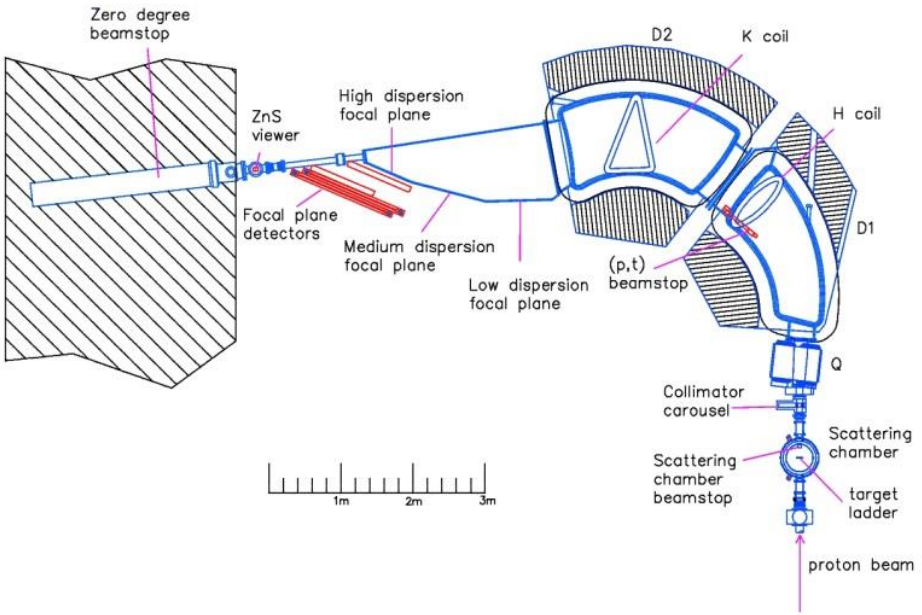


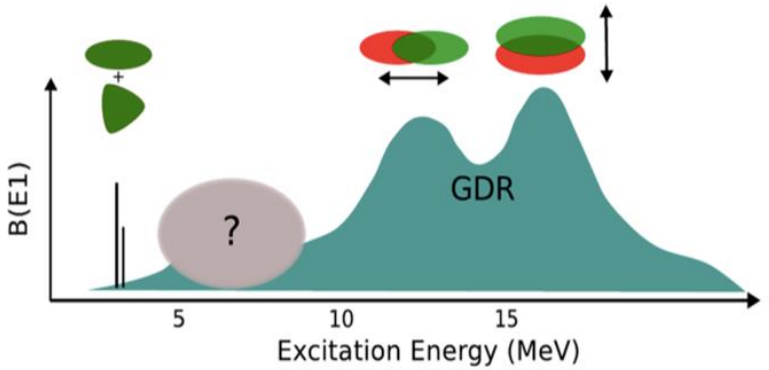


Separated-Sector Cyclotron Facility



The K600 Spectrometer





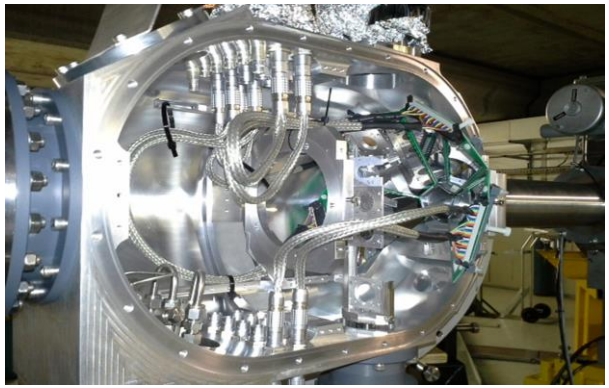
Study PDR in deformed ^{154}Sm via inelastic α-scattering

γ-ray detection allow the identification of E1 strength

- **Cluster structure investigations**
- **Excitation and decay of collective excitations**
- **Astrophysics studies**

K=600 magnetic spectrometer

Recent improvements

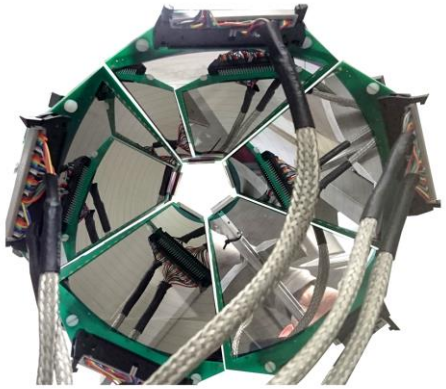


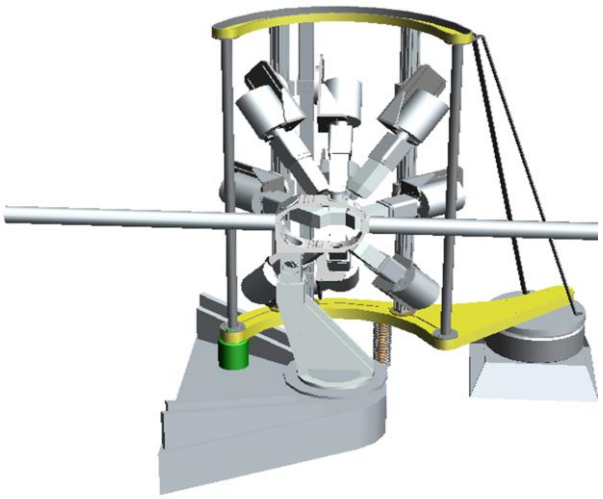
A small chamber: Coincidence experiments with K600 at 0 – 4°

5 DSSSDs cover 26% of 4π

114 to 166 degrees

7 MeV p, 28 MeV α





Particle - γ coincidence with K600 at 0°

8 Clovers at 170 mm from target

Efficiency 0.6% at 6 MeV

First experiment:

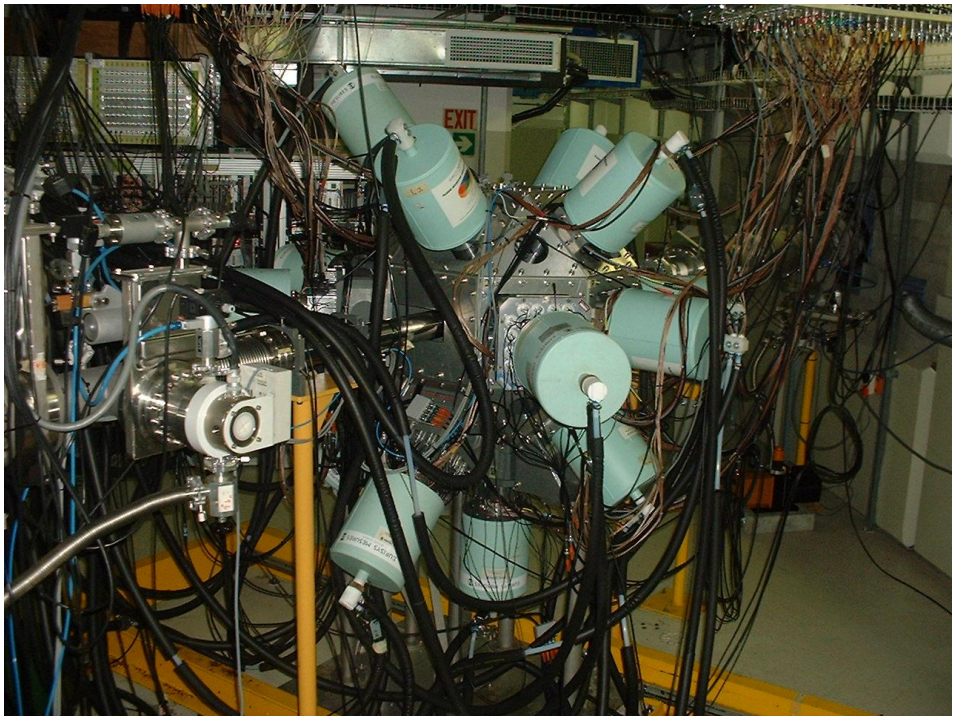
^{154}Sm(α, α'γ) to study the effect of the deformation on the PDR

AFRODITE and γ detectors

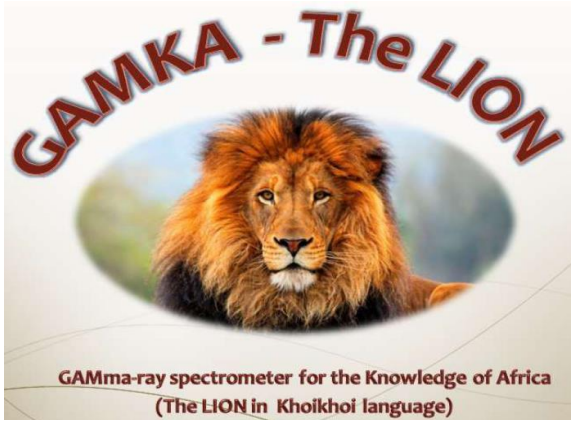
Nuclei typically populated using heavy-ion, fusion-evaporation reactions

9 +5 Compton-suppressed HpGe detectors
8 Segmented planar Ge

Si strip detectors
Neutron wall (plastic scintillator)
Recoil detector
8 Small $LaBr_3$ detectors (50x50mm)



Chiral symmetry in nuclei
Excited 0^+ states
Enhancement of Photon strength function



UNIVERSITY of the WESTERN CAPE

NRF National Research Foundation | iThemba LABS Laboratory for Accelerator Based Sciences

University of Zululand

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

UNIVERSITEIT STELLENBOSCH UNIVERSITY

Combination of **high-resolution + high-efficiency gamma Detectors** in flexible configurations

- **4 clovers**
- **17 large $LaBr_3$ detectors**
- **LN2 liquefier and new filling system**
- **Electronics, HV supplies and DAQ**
- **Two possible new frame designs**

NRF funding of R 35 m approved

Completing AFRODITE

5 clovers added in 2018

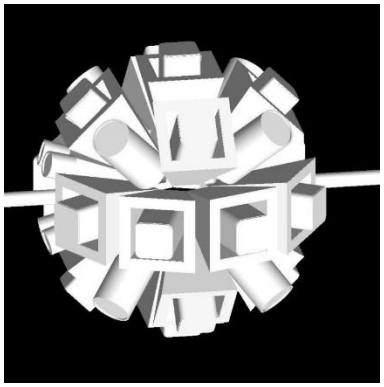
4 from the GAMKA Proposal

Increase from 9 to 18 detectors

Efficiency of 3.6% at 1.3 MeV

(factor 4 increase in γ-γ pairs at multiplicity 10)

4 different angles for improved angular distribution measurements



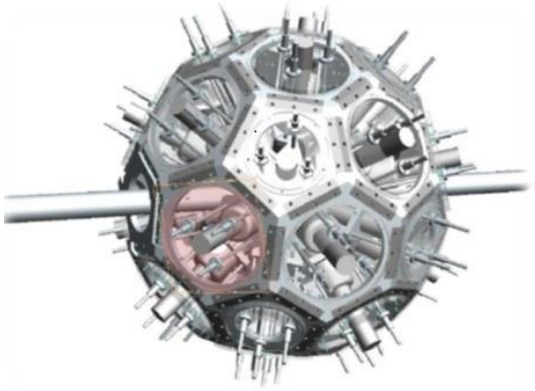
Completing ALBA

ALBA (African LaBr Array):

23 large volume $LaBr_3$ (80 x200mm)

and 8 fast timing $LaBr_3$ (50x50mm)

Efficiency of 4.6% at 10 MeV



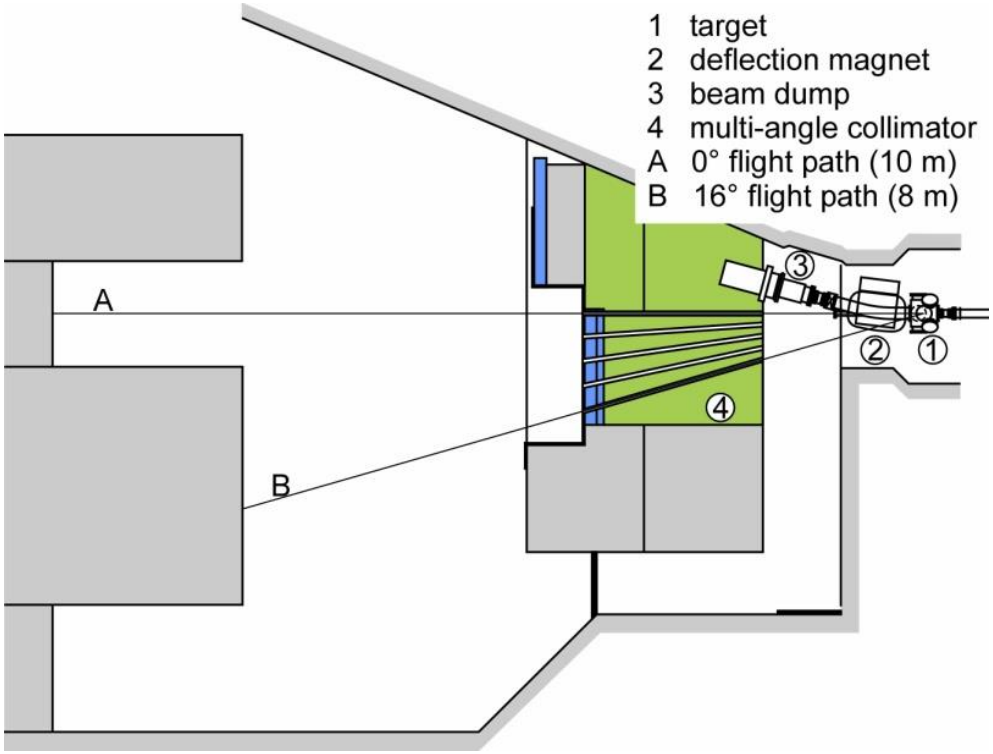
GAMKA:

Combinations of Ge and $LaBr_3$ detectors

e.g. 13 large volume LaBr3 and 17 Clover detectors.

Neutron beam Facility

- Targets:
  - Li, Be: quasi-monoenergetic
  - C: quasi-white (‘grey’)
- Beam currents
  - 3-5 µA (E_p < 100 MeV)
  - 300 nA (E_p = 200 MeV)
- Pulse selection: 1/1 – 1/7
- Time resolution: ≈ 1 ns
- Flight paths:
  - 10 m (0°)
  - 8 m (16°)
- Fluence rate (1 mm Li):
  $j \approx 1 \cdot 10^3$ cm^{-2} µA^{-1} at 10 m



- **neutron dosimetry**
- **radiobiological effectiveness of fast neutrons**
- **detector development**
- **Neutron induced cross sections**

Proton Therapy

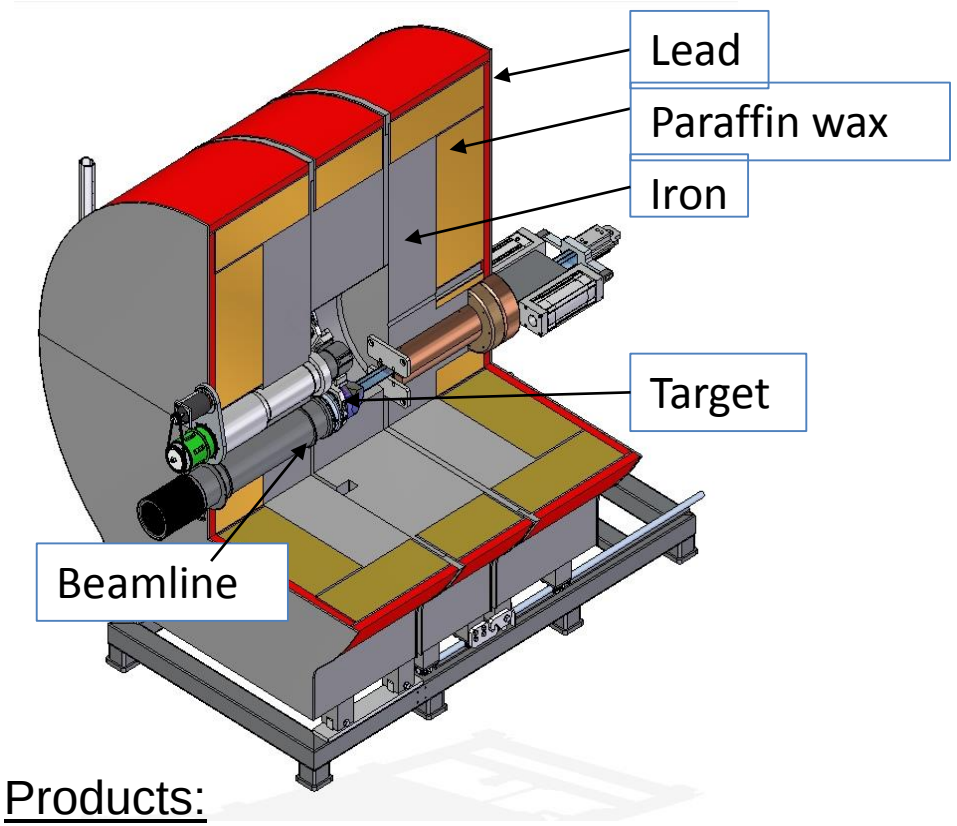
Proposed Fields of Research

- Focus on research projects that were designed around the existing hadron therapy vaults, based on a combination of physics and biological techniques
- Highlighted projects that are currently ongoing or will start in the near future:
  1. Out-of-field radiation risks in proton therapy
  2. Radiosensitivity of haematopoietic stem cells
  3. Variation of RBE along the proton depth dose profile
  4. Microdosimetry
  5. Early and late central nervous system effect in normal rat brain
- A full list of future projects can be found in the long range plan document

Isotope Production

2 Bombardment Stations
66 MeV proton beams
at 250 μA and 80 μA
respectively

11 MeV Cyclotron for ^{18}F



Products:

Local Market

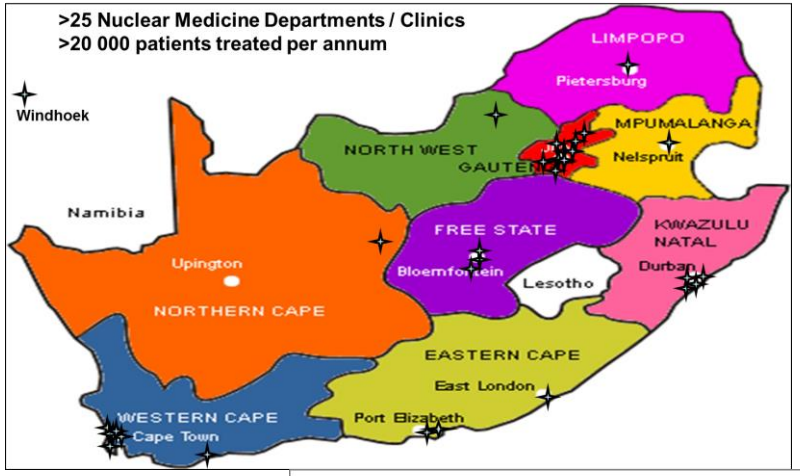
^{18}F (1.8h), ^{67}Ga (3.3d) and ^{123}I (13.2h)

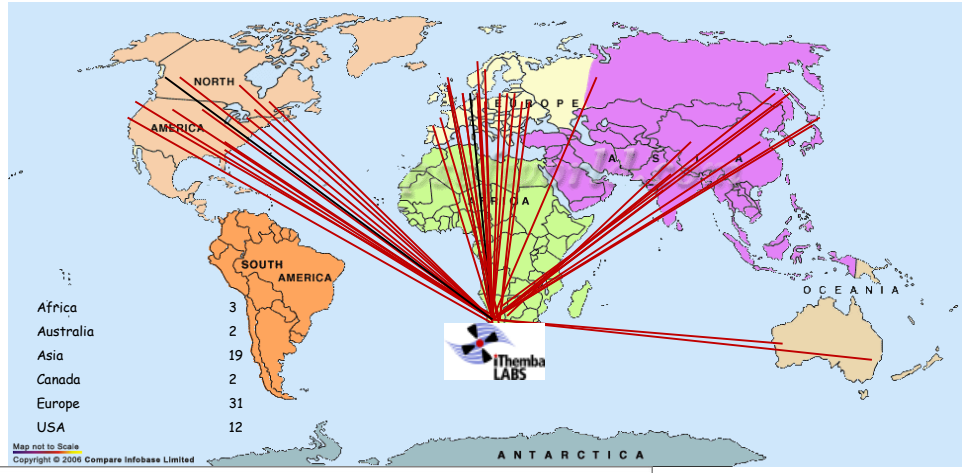
Local and export

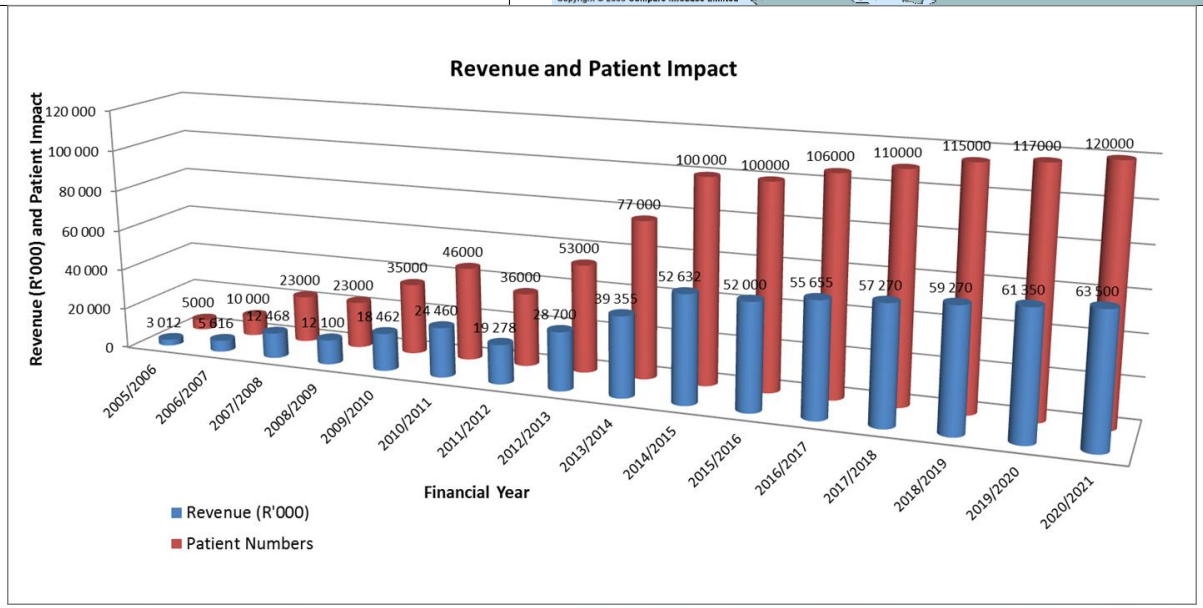
$^{68}Ge/^{68}Ga$ generators (271d/67m)

^{82}Sr (25.5d), and ^{22}Na (2.6y)

iThemba LABS:
World Leader in Accelerator Produced Radioisotopes for Medicine



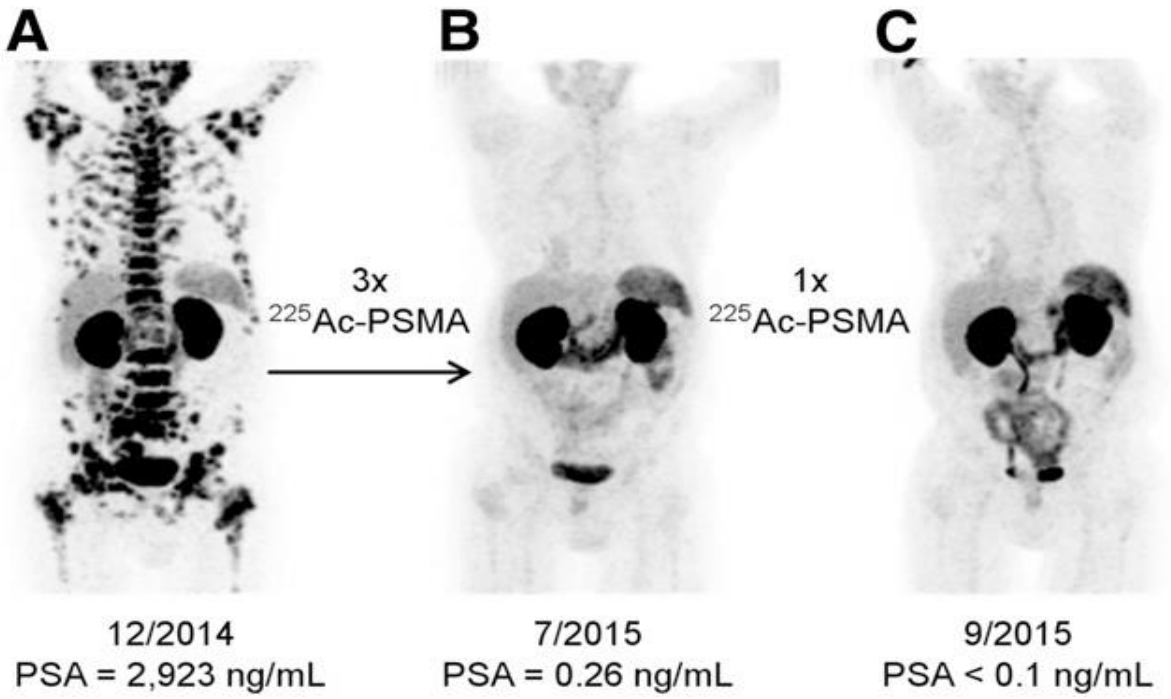




Research and development of new generation radio-isotopes

Prostate-specific membrane antigen (PSMA) radioligand therapy

^{225}Ac-PSMA/^{68}Ga-PSMA: First-in-human; total response

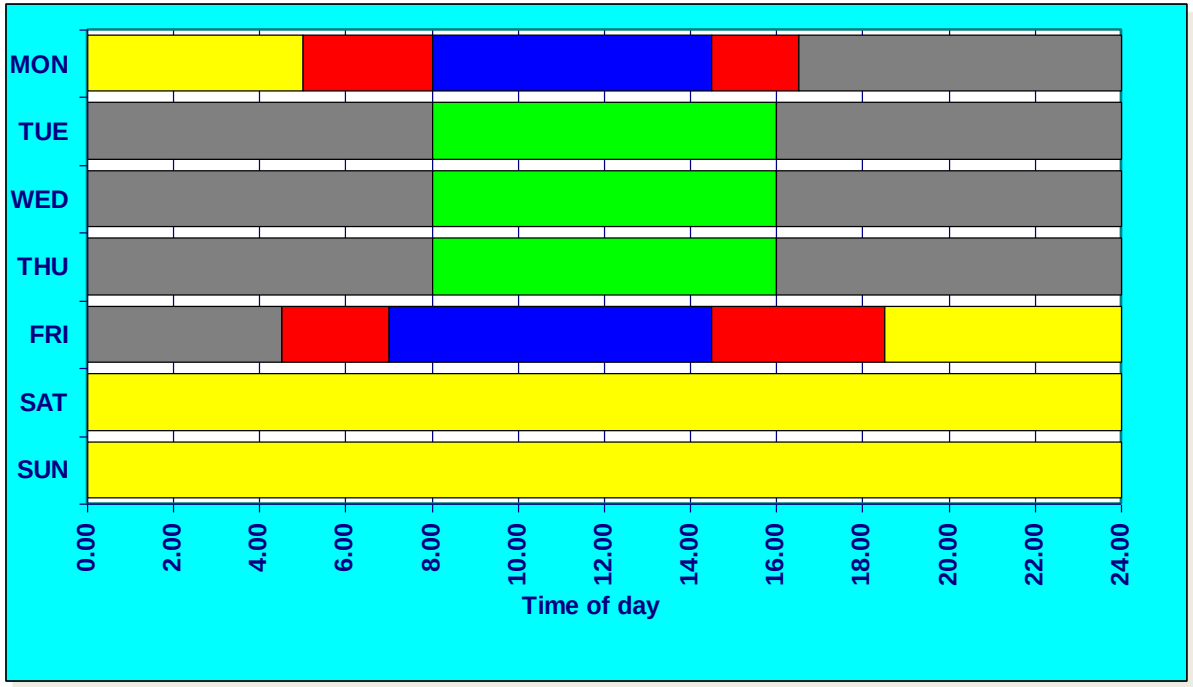


Kratochwil et al., J. Nucl. Med. 57 (2016) 1941 - DKFZ, Heidelberg

^{211}At [^{211}At-MABG] can also be used

- Production at iThemba LABS under investigation

SSC Beam Schedule



© Nuclear Physics

© Neutron Therapy

© Proton Therapy

© Energy Change

© Isotope Production

New Beam Schedule is more flexible

- **short lived isotope production still need beam Monday – Wednesday**
- **research can have extended weekends**
- **long-lived isotopes sometimes use full week**
- **beam time split about 50% research / 50% isotope production**

Future of iThemba LABS

The Facility is currently faced with two options:

1. Maintaining the *status quo*.
2. Embark on a sustainable and globally competitive NRF research facility through *research infrastructure renewal*.

The South African Isotope Facility (SAIF)

iThemba LABS creating new opportunities for a shared vision through building collaborations, and shaping the future

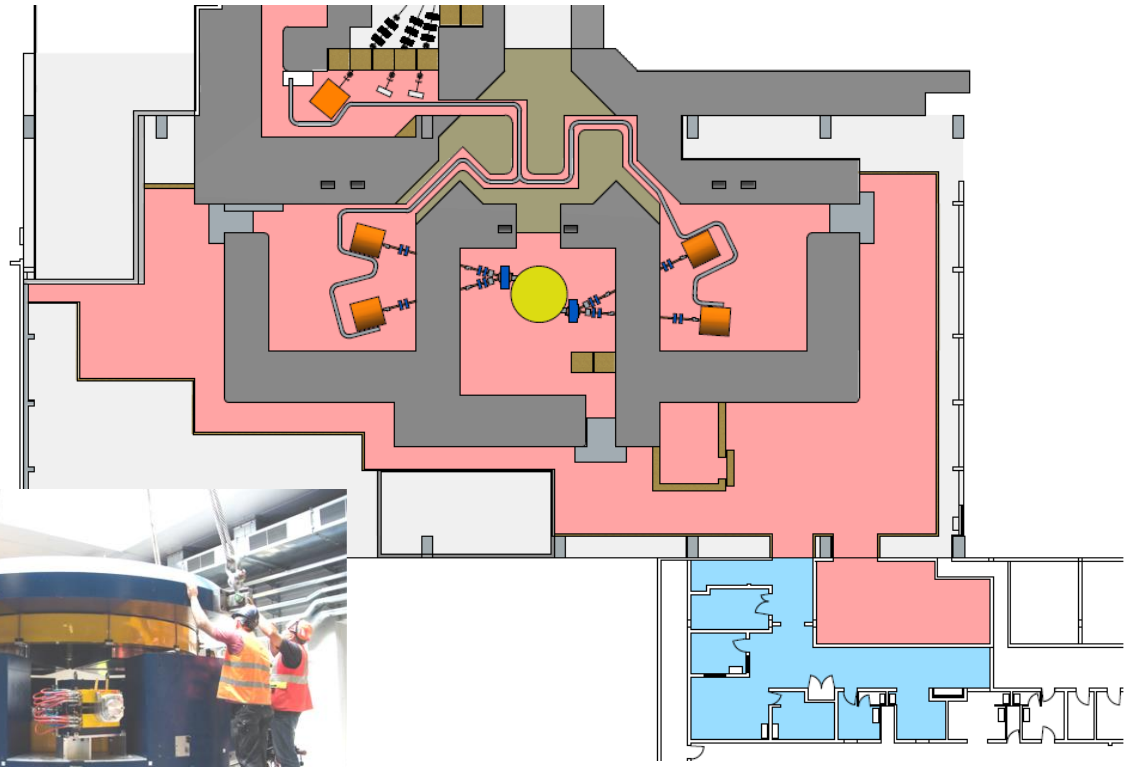
Infrastructure renewal

In planning for a sustainable future for the Facility, the NRF has developed a robust strategy to support globally competitive and socially relevant research. The South African Isotope Facility (SAIF) project is dependent on an investment to upgrade the existing research infrastructure in order to increase overall productivity and expand the science capability. The SAIF project will consist of two phases:

- **Phase 1**- **Accelerator Centre for Exotic ISOTOPES (ACE-ISOTOPES)**
  - Increased capacity for the R&D as well as production of Isotopes
  - Timeline - 4 years to operations

- **Phase 2**- **Accelerator Centre for Exotic BEAMS (ACE-BEAMS)**
  - Isotopes for Astrophysics - synthesis of elements in the universe
  - Timeline – 8 Years to operations

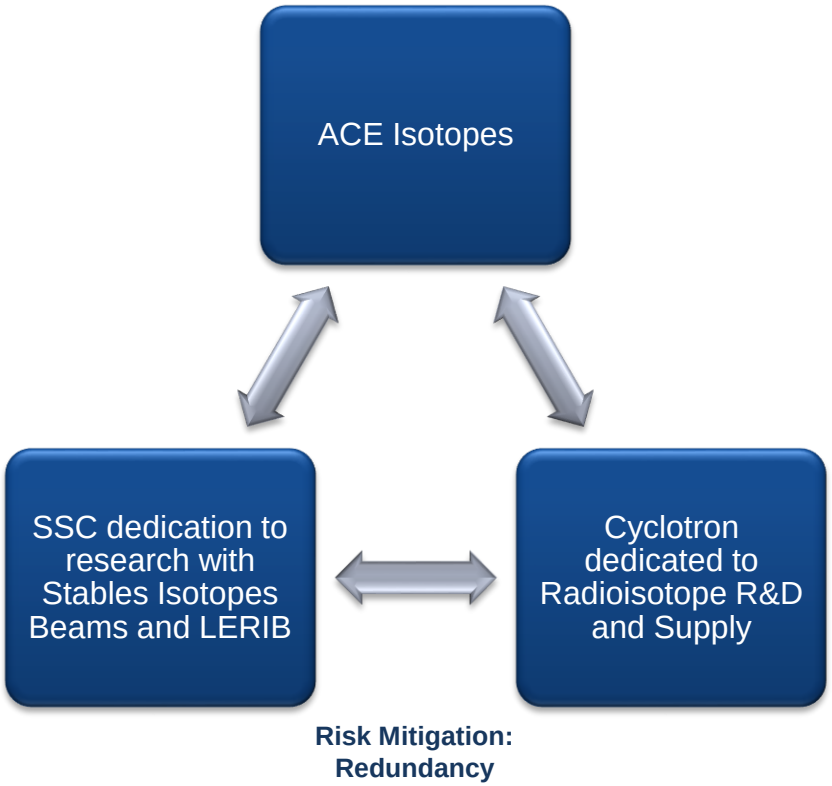
Accelerator Centre for Exotic Isotopes (ACE Isotopes)



BEST 70p Cyclotron
H^- Beam 750 μA
(two simultaneous beams)

- **Increased capacity for the production of Isotopes**
- **Timeline - 4 years to operations**

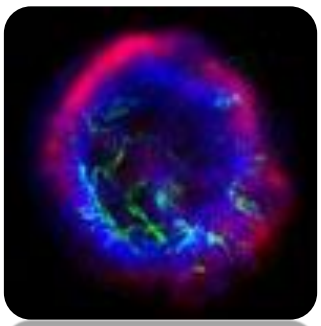
Phase 1: Science

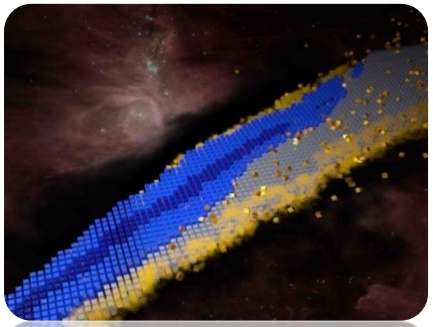


Risk Mitigation: Redundancy

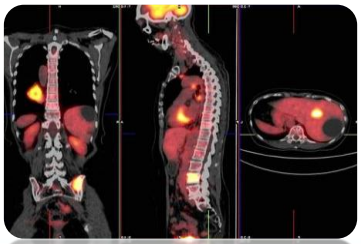
The modern Nuclear science addresses two main fundamental goals:

- Understanding the core of matter
- Understanding the fuel of stars.

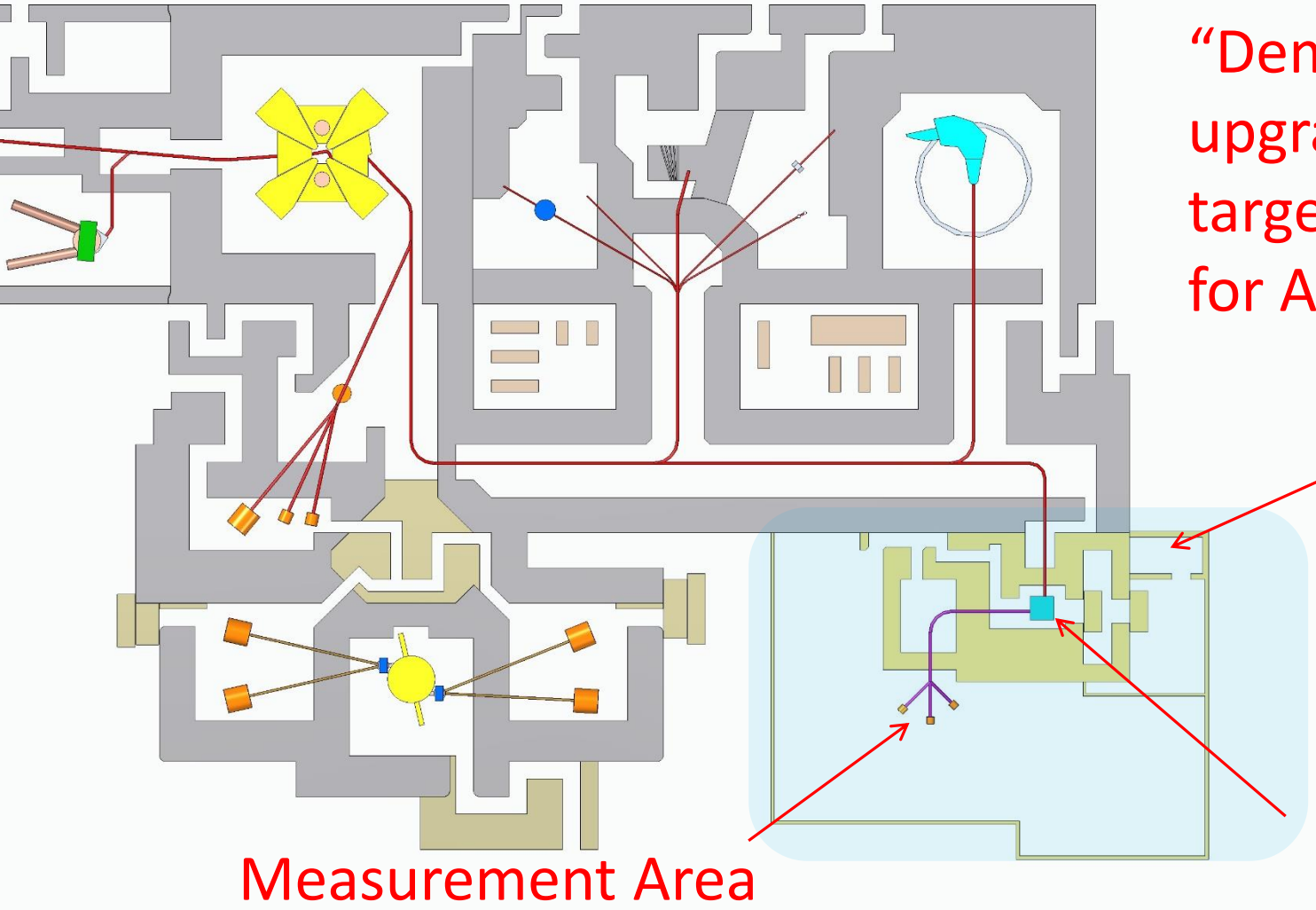




The modern nuclear science aims at making its knowledge and technological progress best used to benefit society?



Low Energy RIB facility “LERIB” (ISOL)

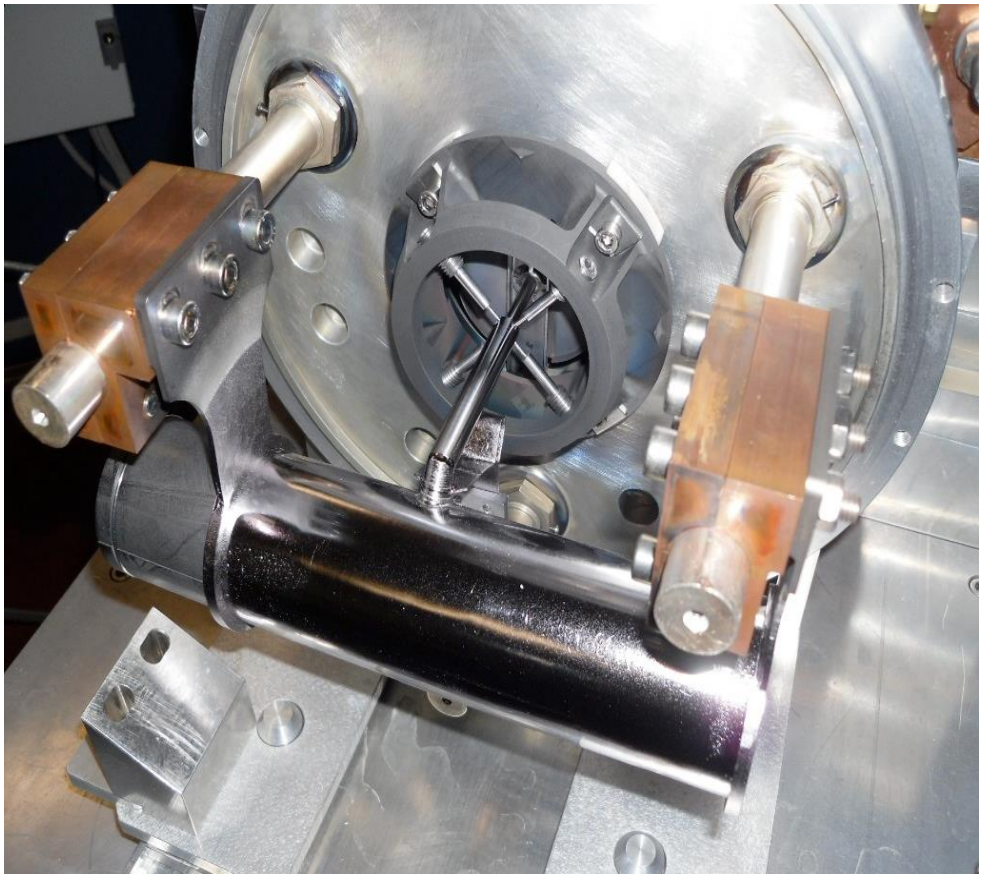


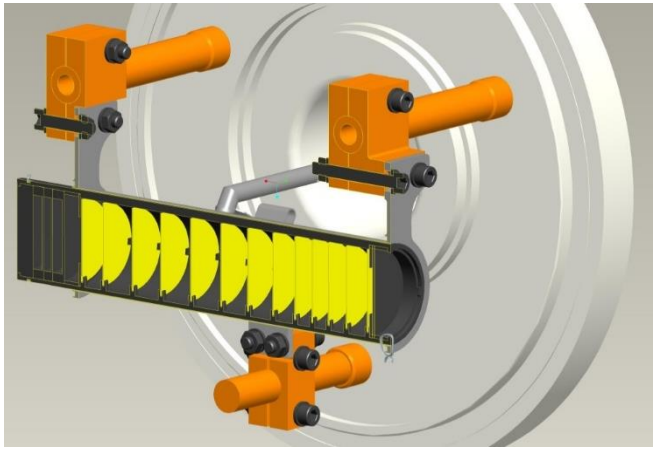
“Demonstrator” upgraded to be target/ion-source for ACE Beams

Target Storage

Target/ Ion-source

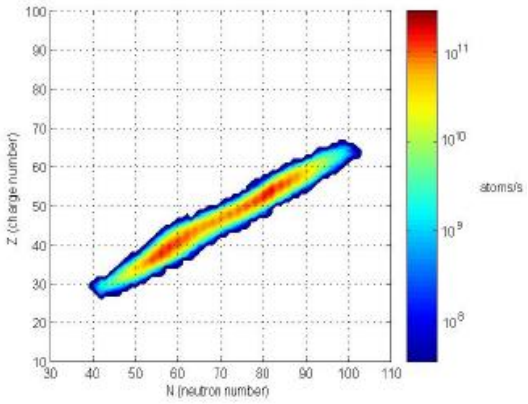
The SPES target (chamber lid removed), designed for a 70 MeV proton beam entering from the right. The heating current flows through the Ta tube, between the copper clamping bars at each end





CAD drawing of the SPES target assembly, showing the UC_x disks (yellow) in a graphite tube and also the beam dump disks (dark grey).

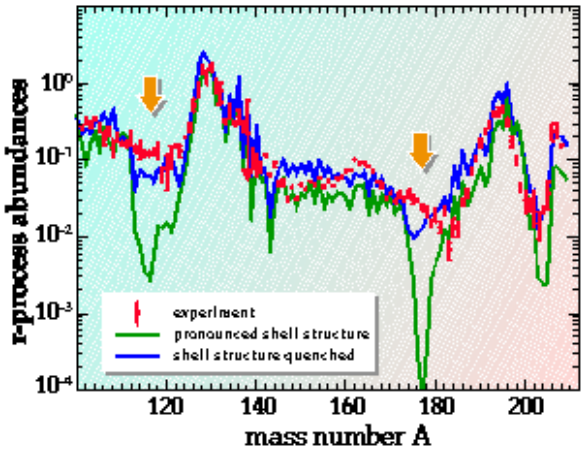
LERIB: Making Radioactive Beams at iTL



Proton induced Fission of Uranium

(p,xn), (p,yp,xn), (p, za, xn) ……

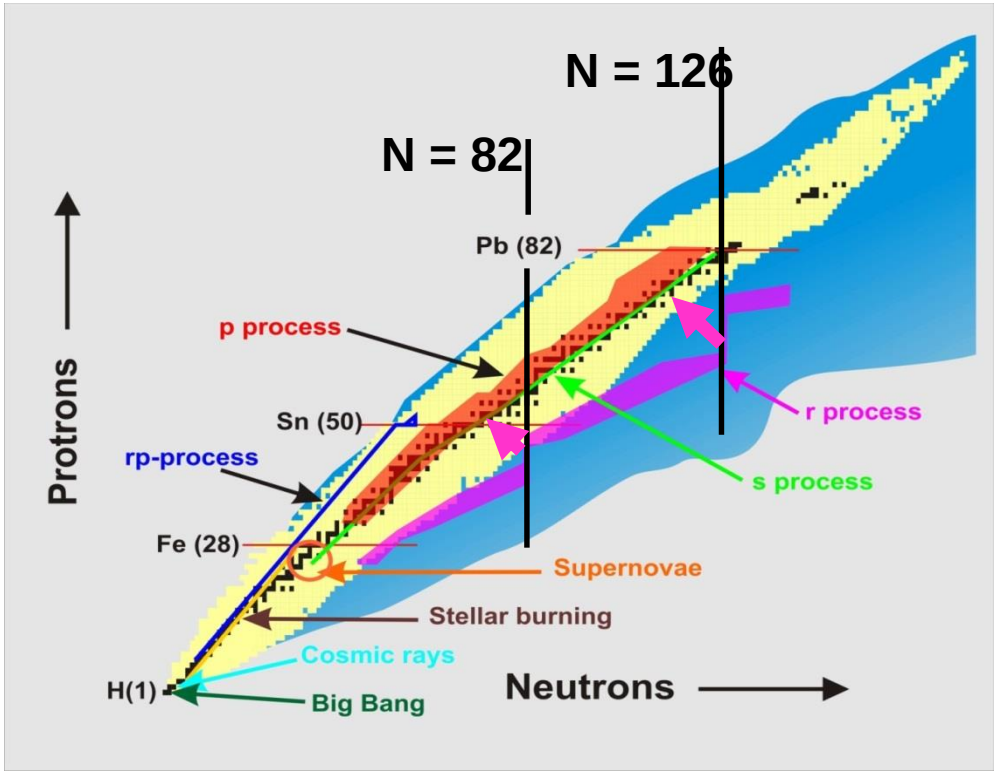
Synthesis of the elements



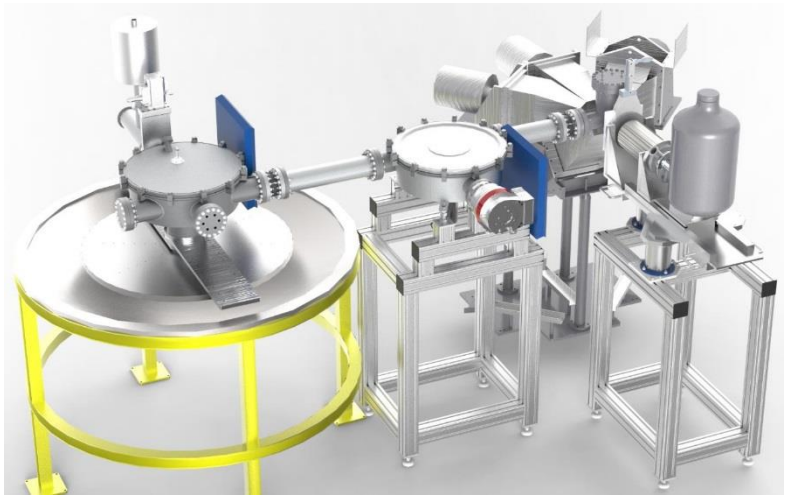
Freiberghaus APJ 518(98)

Astrophysical r-process

Massive neutron bombardment in Supernova



Towards β-decay spectroscopy with LERIB



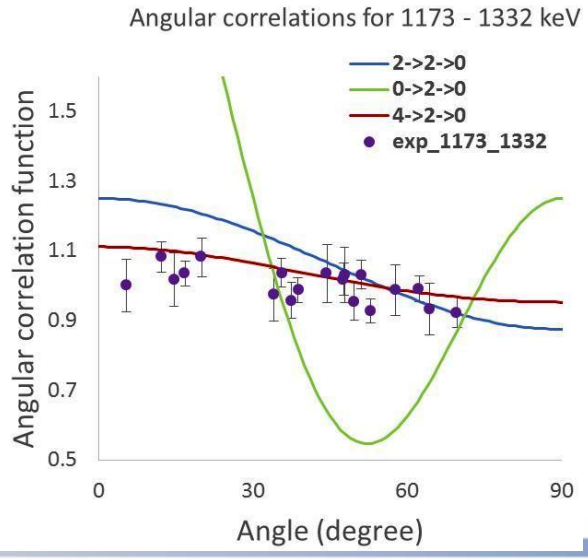
First Experiment with Stable beam:

3 clovers

1 TIGRESS segmented clover

SiLi detector for conversion electrons

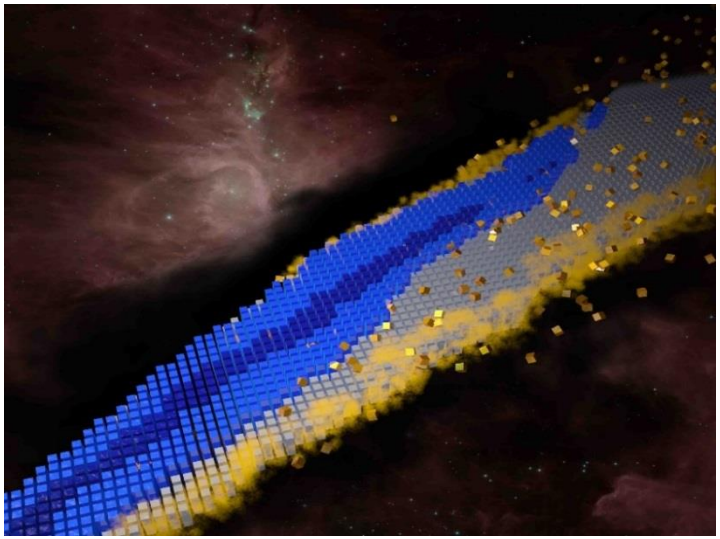
Study of the decay of ^{98,100}Rh to ^{98,100}Ru
From the ^{16}O+^{87}Rb reaction



A segmented clover detector can be s very powerful tool for precise angular correlation measurements

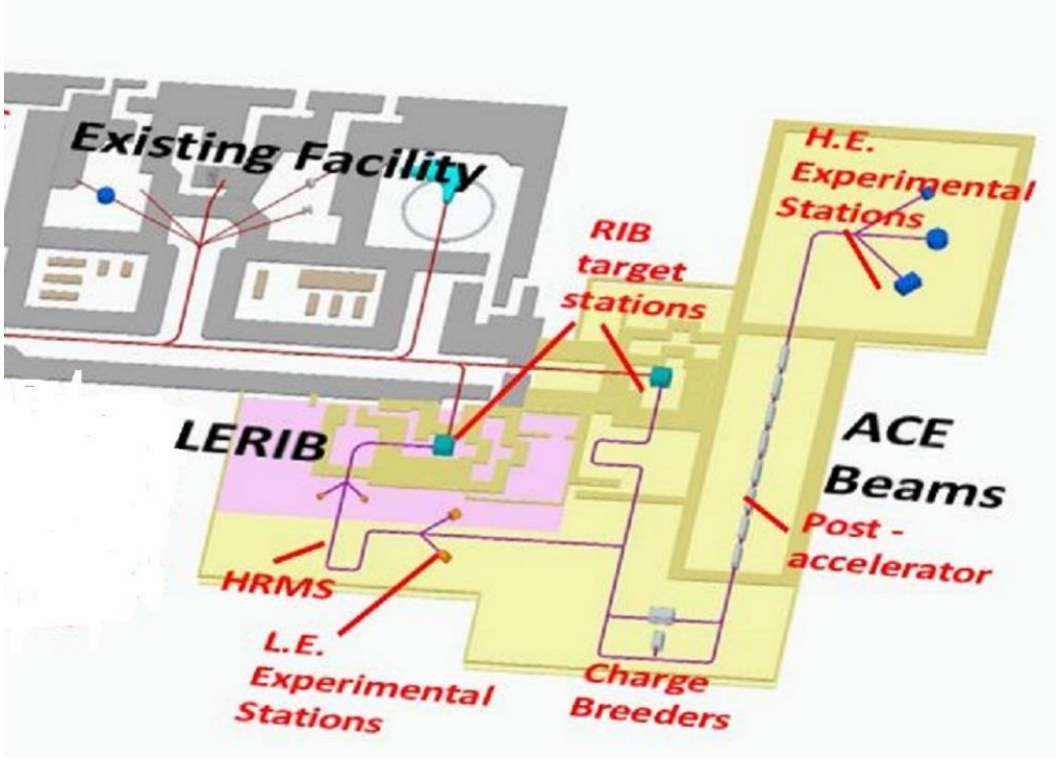
PHASE 2 – Accelerator Centre for Exotic Beams(ACE-Beams)

Accelerated radioactive Beams



The Nuclear Landscape and the Big Questions

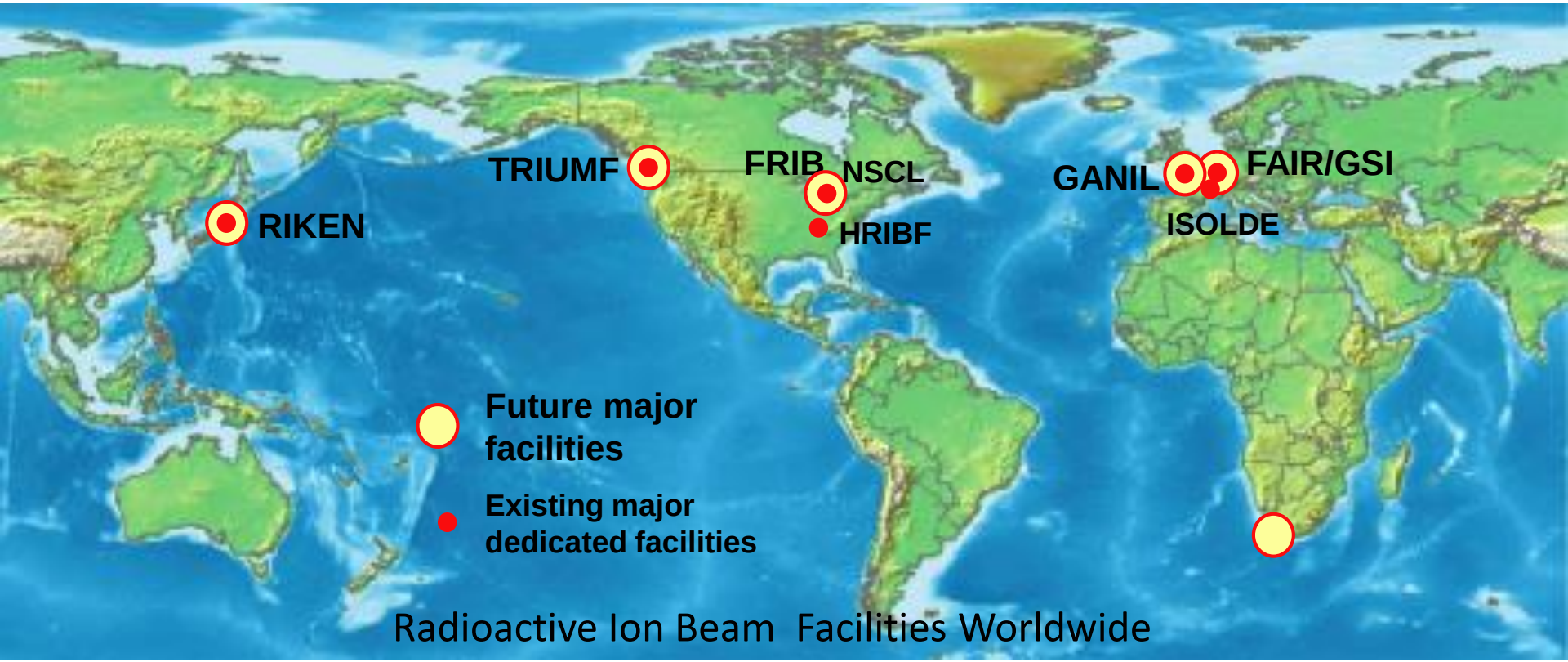
- Isotopes for Astrophysics - synthesis of elements in the universe
- Timeline – 8 Years to operations



ACE-Beams

The addition of a post accelerator to LERIB - ACE Beams

SAIF in the world



The South African Institute of Nuclear Technology and Science (SAINTS)

PhD level

- *Medical Physicist degree*
- *Radiopharmacist degree*

Master's Degrees & Specialisation

- *Nuclear Engineering Master's degree*
- *31 Master's degrees*
  Master of Nuclear Energy

Post-graduate level

2 years' Higher Education

- *RP Technician diploma*

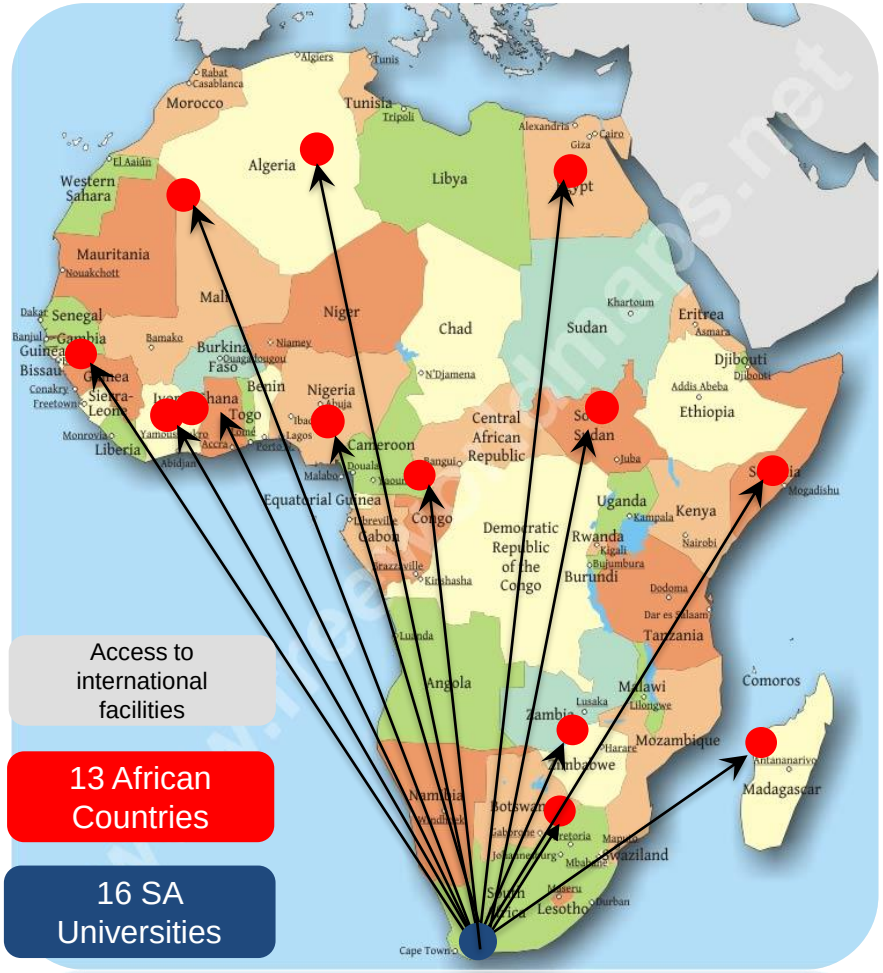
High School leaving level or below

- *RP Technician certification*
- *Joint diplomas*

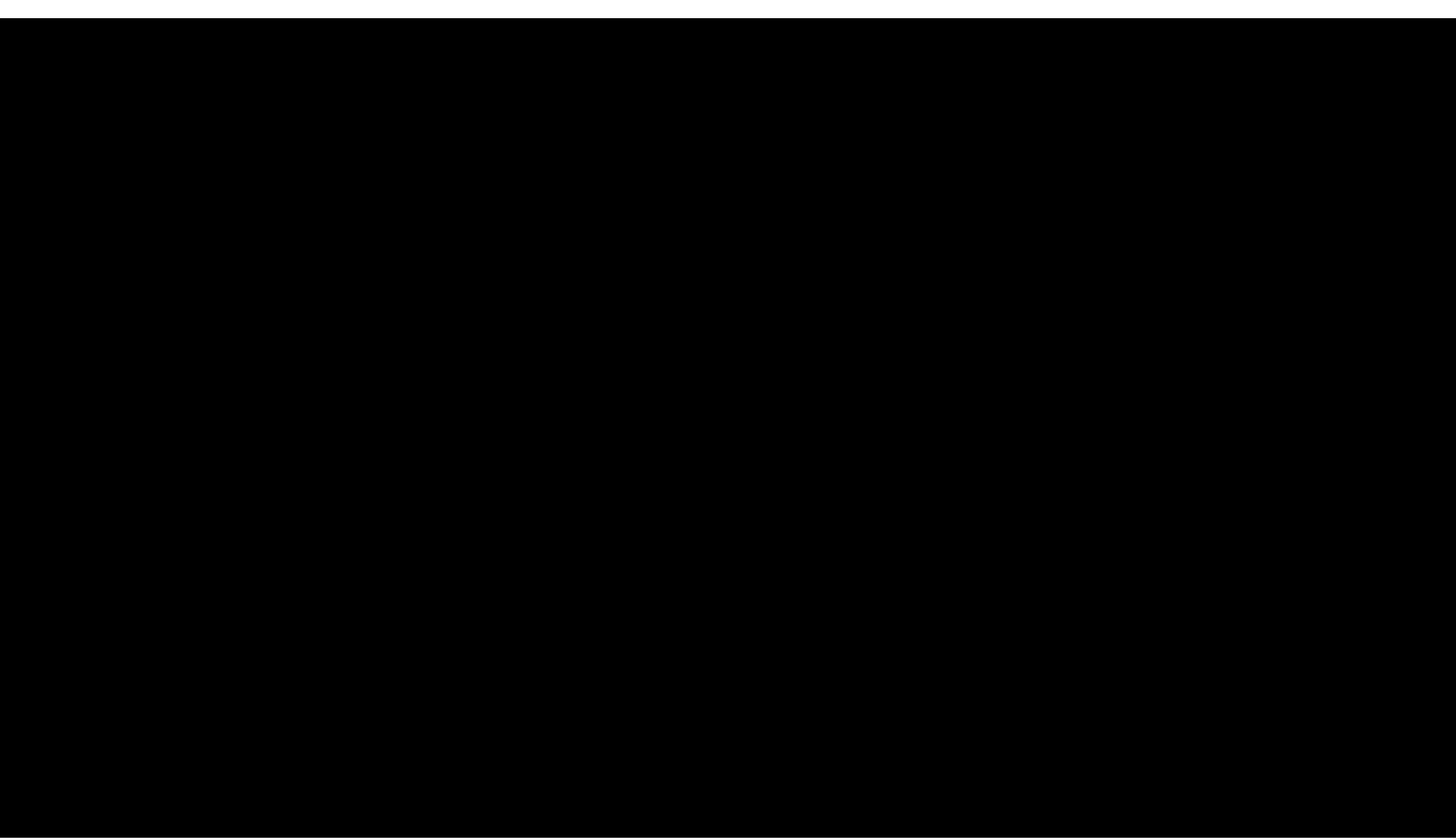
Entry level

C O N S I S T E N C Y

iThemba LABS with SAIF and SAINTS



Expanding scientific cooperation through Africa



Thank you

science
& technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA