

# Research at iThemba LABS – opportunities in nuclear science and applications

Mathis Wiedeking

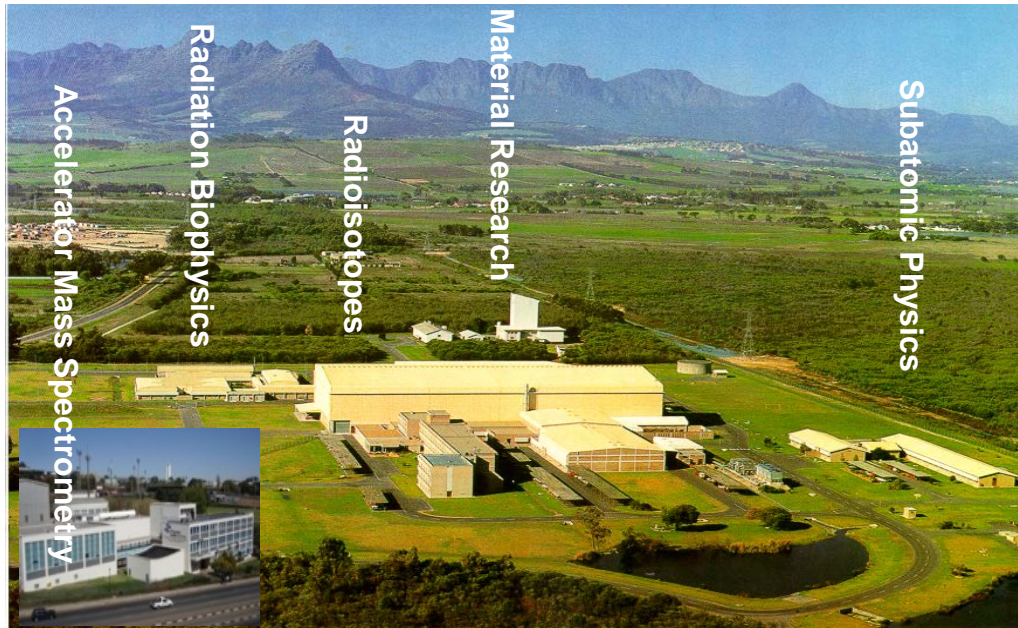
*Department of Subatomic Physics*



- iThemba LABS
- DSP

# iThemba LABS : National Facility for *research, development and training*

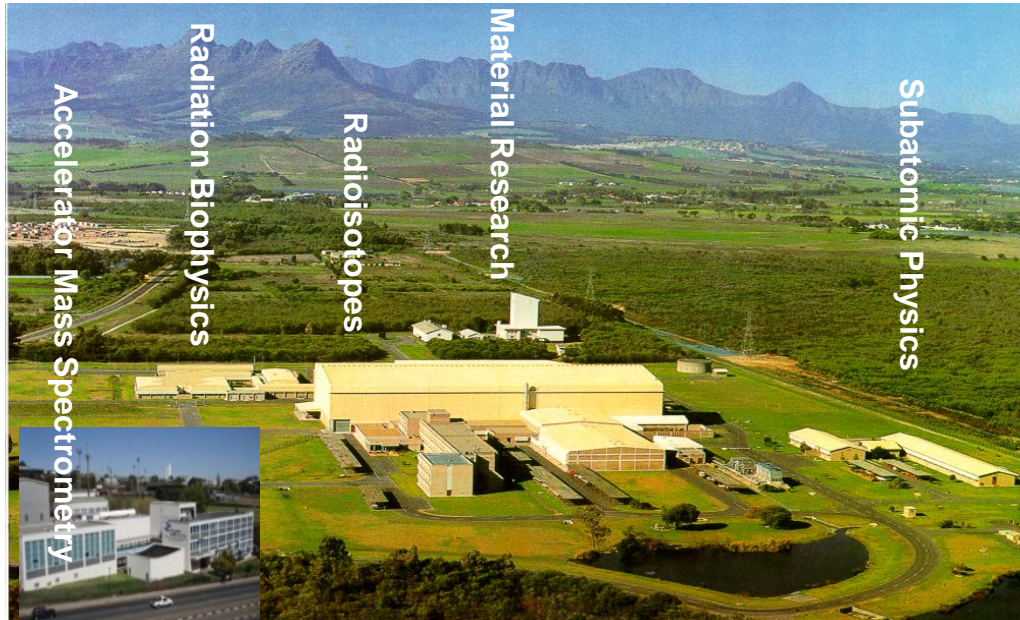
Largest National Research Facility in SA and the largest accelerator facility in the southern hemisphere:



- ~55% of the NRF budget for research facilities.
- Annual Budget ~ 22M\$
- Isotope production ~4M\$
- Permanent staff ~300
- Users ~150
- ~ 150 publications per year
- ~ 90 students per year

# iThemba LABS : National Facility for *research, development and training*

Largest National Research Facility in SA and the largest accelerator facility in the southern hemisphere:



Injector cyclotron 1



Separated sector cyclotron



6MV Tandem



K11 Cyclotron



Injector cyclotron 2

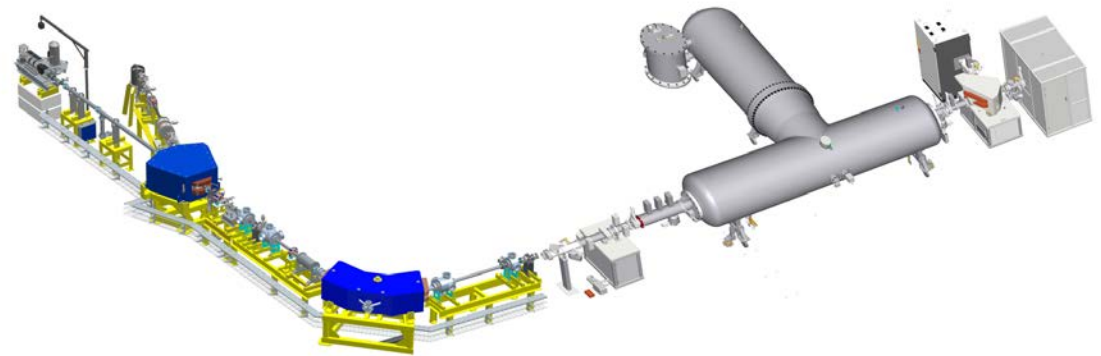
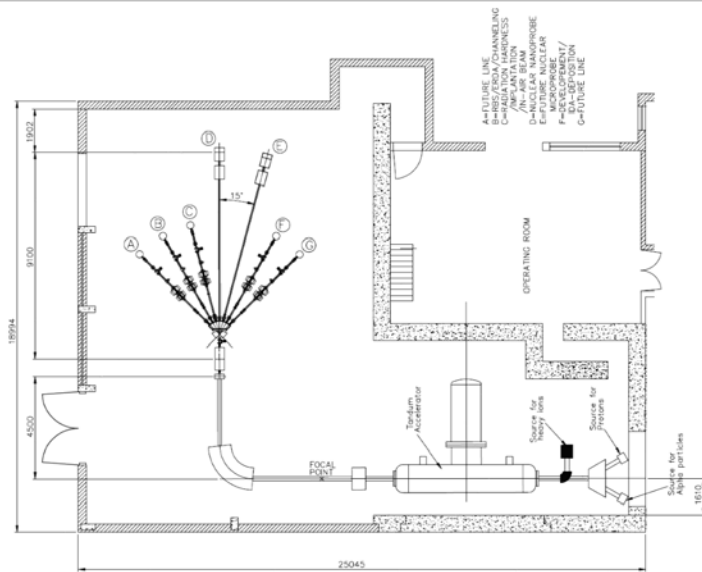
Infrastructure Renewal



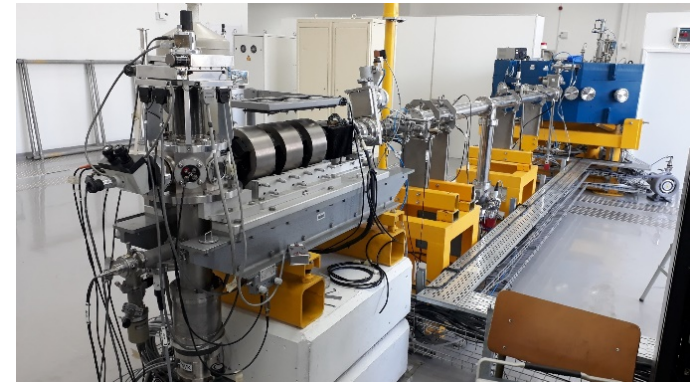
3MV Tandatron

# Material Research: Tandetron

2017 : Replacement of the 52 year old Van de Graaff with 3MV Tandetron

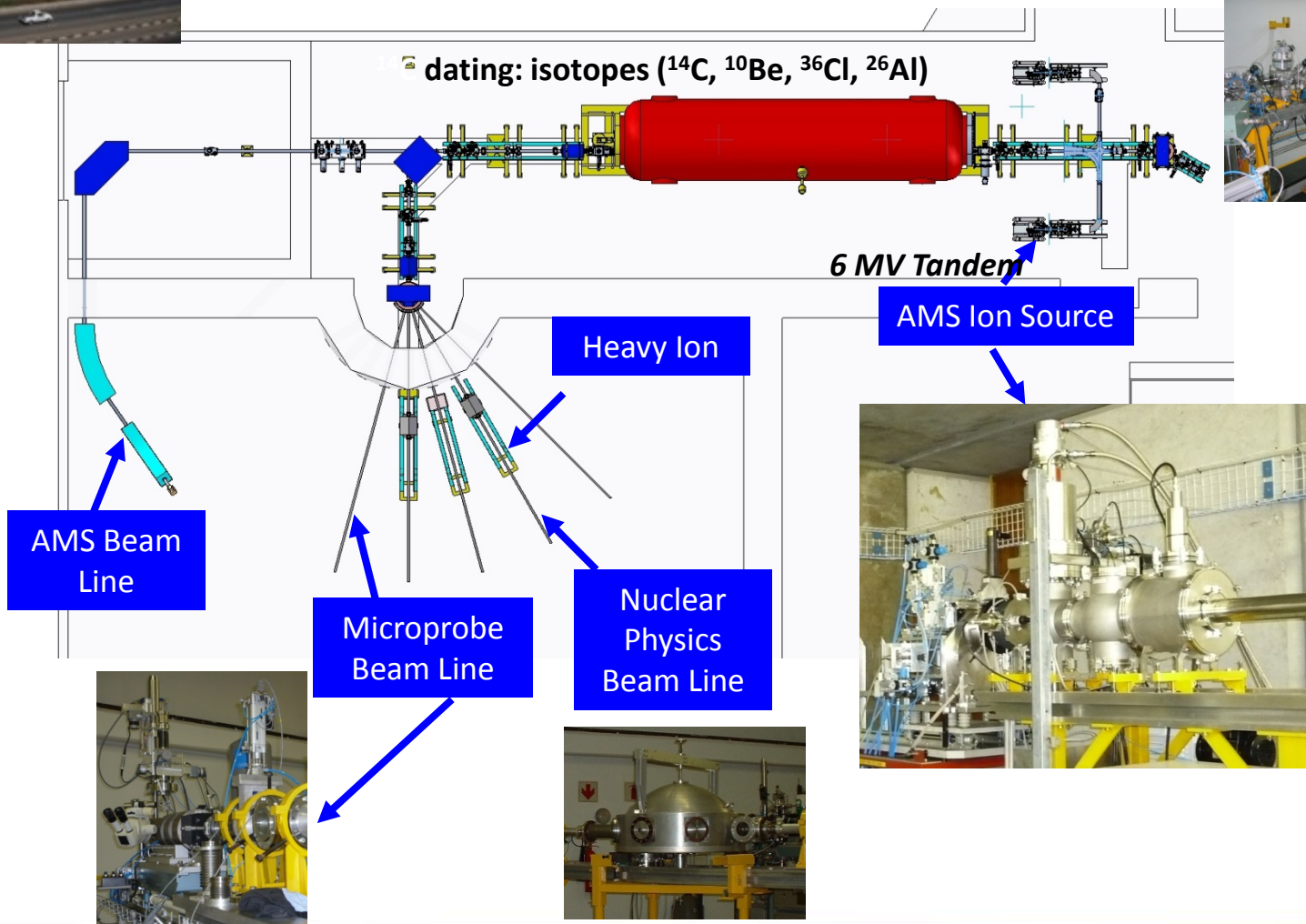


2 High Intensity Multicusp Ion Sources for protons and alpha beams

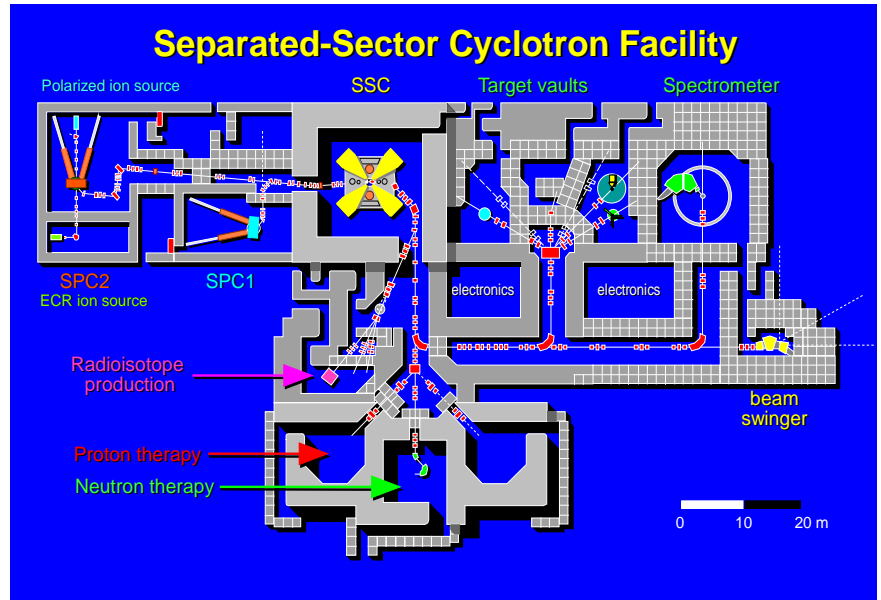
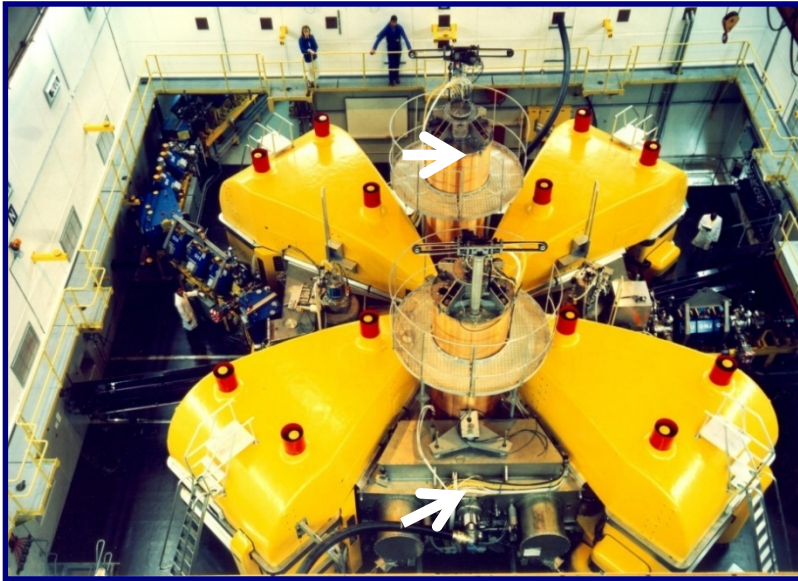


# iThemba LABS: TAMS

6 MV Tandem has been refurbished.



# iThemba LABS: SSC (Separated Sector Cyclotron)



Subatomic Physics / Radiation Biophysics / Pharmaceutical Radioisotope Production

- 30 years
- Operating 6000 h/year
- ~12% unscheduled shut-down
- ~70 million Rand in refurbishment

# Radiobiology: from therapy to research



➤ **Research in radiobiology and radiation physics related to hadron therapy, with a strong emphasis on radiobiological modelling for treatment planning**



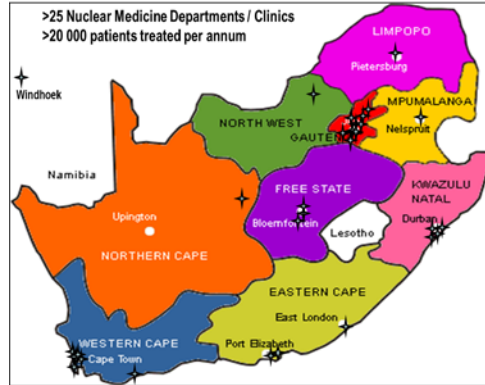
science  
& technology

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Science and Technology  
REPUBLIC OF SOUTH AFRICA

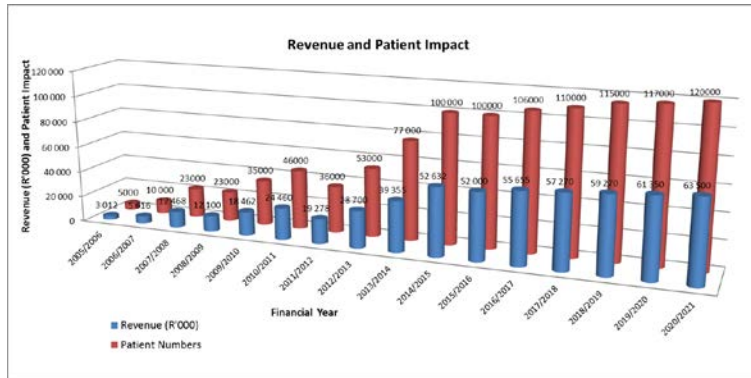
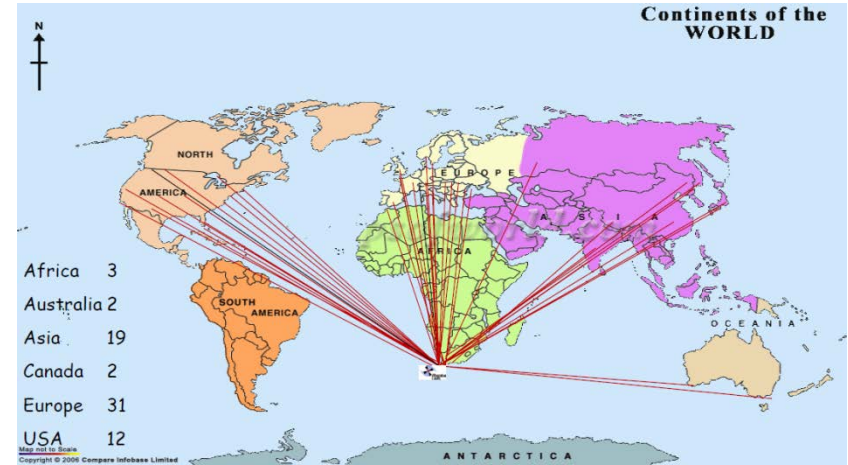


# Accelerator Produced Radioisotopes for Medicine

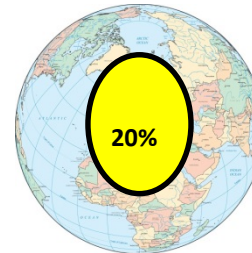
RADIONUCLIDE	HALF-LIFE
$^{18}\text{F}$	1.83 h
$^{67}\text{Ga}$	78.3 h
$^{81}\text{Rb}/^{81\text{m}}\text{Km}$	4.58 h
$^{123}\text{I}$	13.2 h
$^{68}\text{Ge}/^{68}\text{Ga}$	$^{68}\text{Ga}=68$ min $^{68}\text{Ge}=271$ days
$^{82}\text{Sr}$	25 days
$^{68}\text{Ge}$	271 days
$^{88}\text{Y}$	106.6 days
$^{109}\text{Cd}$	453 days
$^{22}\text{Na}$	2.602 years



Radiopharmaceuticals mainly used for diagnostic and/or therapeutic purposes in nuclear medicine.

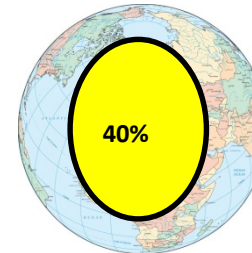


$^{82}\text{Sr}$  (irradiated Rb target)



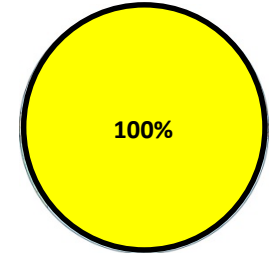
1 exclusive client

$^{68}\text{Ge}/^{68}\text{Ga}$  generator



>80 clients

$^{22}\text{Na}$  positron sources



>40 clients



science & technology

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iThemba LABS  
Laboratory for Accelerator Based Sciences



# Subatomic Physics

Research in:

Hadron Matter (ALICE CERN)

Particle Physics (ATLAS CERN)

Applied Nuclear Physics (environmental radiation, chip testing, ...)

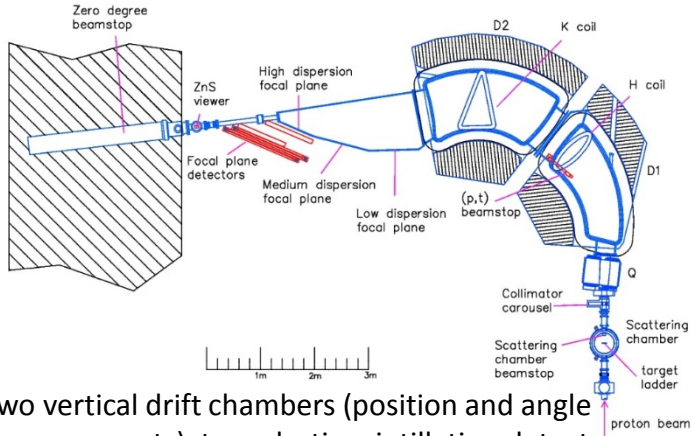
Nuclear Physics (structure, astrophysics, reactions)

Majority of research programs driven by beams from the SSC.



- User facility: for local universities, but also for users from rest of the world.
- Physics beam not restricted to weekends any longer.
- <https://pac.tlabs.ac.za/>

# K=600 Magnetic Spectrometer

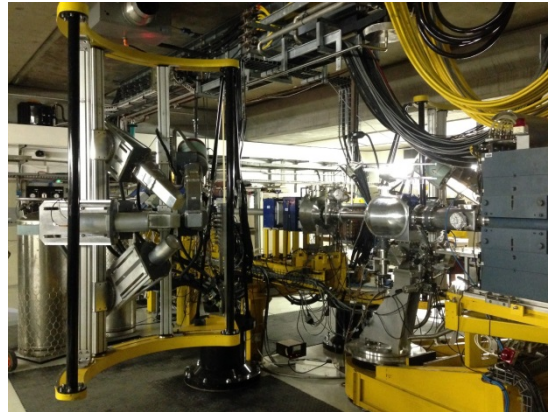
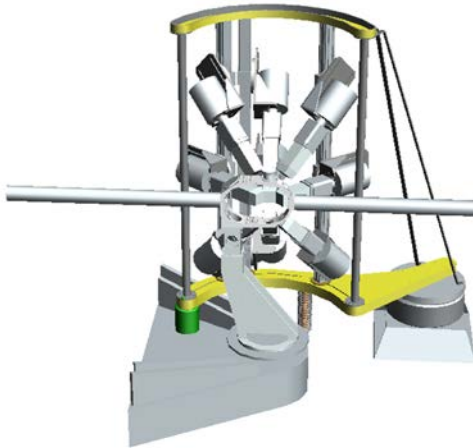


Two vertical drift chambers (position and angle measurements), two plastic scintillation detectors (trigger and particle identification)  
 Full solid angle 3.5 msr and efficiency 80%

K600 is one of two facilities capable of high energy resolution ( $\leq 100$  keV FWHM) measurements at zero degrees, with low background to the measured spectrum, for medium energy ( $E \sim 50-200$  MeV/A) light ions (p,d,t,He).



$\gamma$ -ray array coupled to K600



RS: R Neveling & R Smit

# K600: new focal plane detector

## Present Limitations:

- No low energy detection capability (e.g.  $^3\text{He}$ ,  $\alpha$  at 10-20 MeV/u or p,d, t at <30 MeV)
- No heavy ion capability
- Loss of resolution e.g. in  $(\alpha, \alpha')$  due to multiple scattering in exit windows

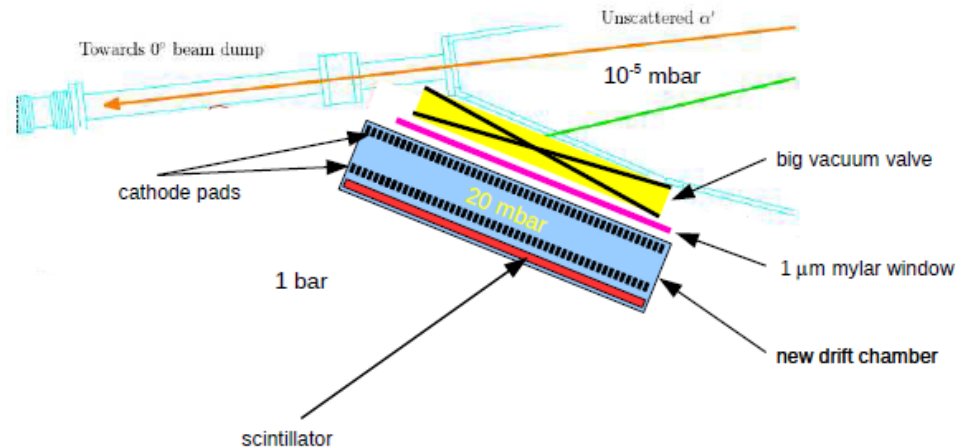
**Goal: add new capability to detect with high resolution low-E or high-m particles.**

## Existing detectors: Multi Wire Drift Chambers

- ⇒ gas filled
- ⇒ operates at 1 bar
- ⇒ wireplanes sandwiched between HV planes
- ⇒ electrons drift horizontally
- ⇒ position determined from wires

## New detectors: Proportional Drift Chambers

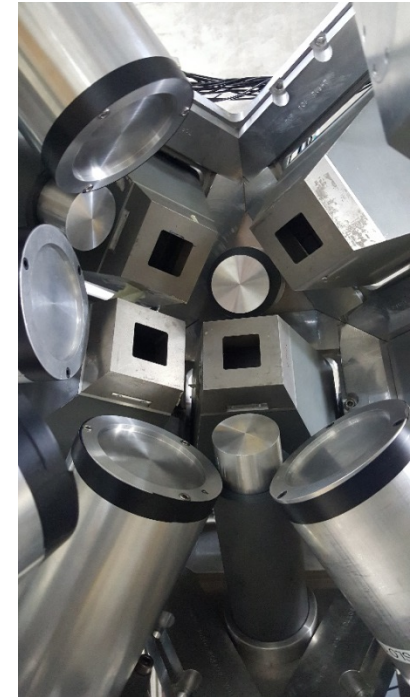
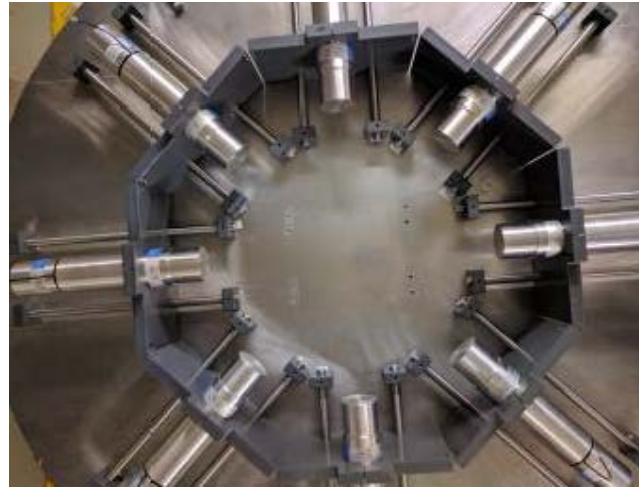
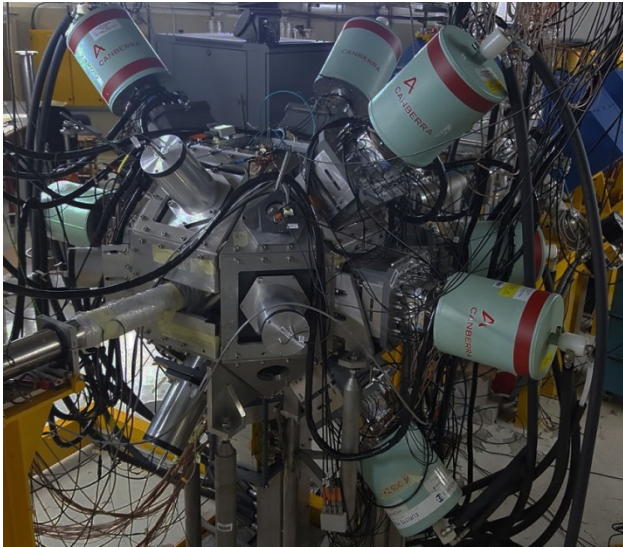
- ⇒ gas filled
- ⇒ operates at low pressure (~20 mbar)
- ⇒ no wires, HV plane at the top
- ⇒ electrons drift vertically
- ⇒ position determined from cathode pads



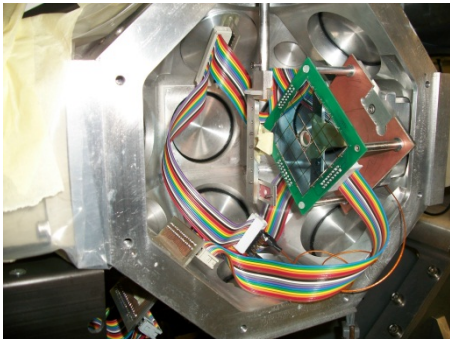
Solution: MICROMEGAS detector

RS: R Neveling & R Smit

# Gamma-ray array(s)



- iThemba LABS embarked on mission to expand capabilities ~4.5M Euro total investment.
- AFRODITE (Clover, BGO and LEPS) to be doubled.
- Fast-timing array: 2.5x2.5cm LaBr3:Ce
- Segmented Clover detector.
- African LaBr Array: ALBA 89x203mm LaBr3:Ce
- Coupled to CSI, recoil det., silicon, solar cells, plunger, neutron wall.
- Digital electronics (XIA).



RS: P Jones, E Lawrie, L Pellegrini, M Wiedeking

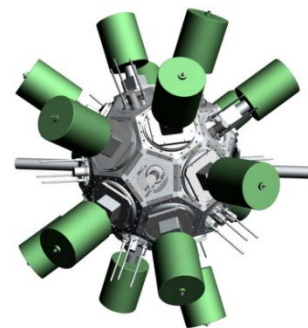
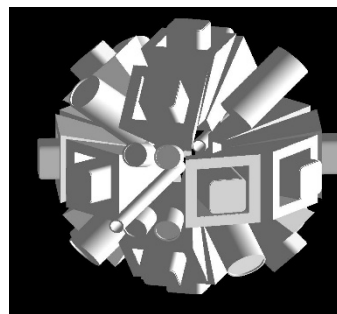
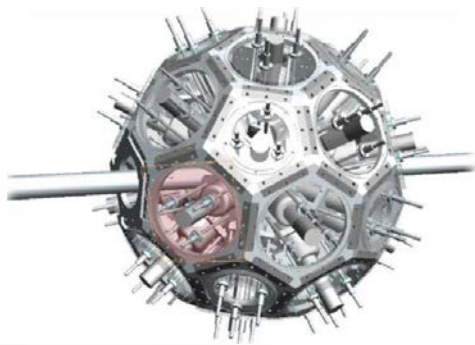
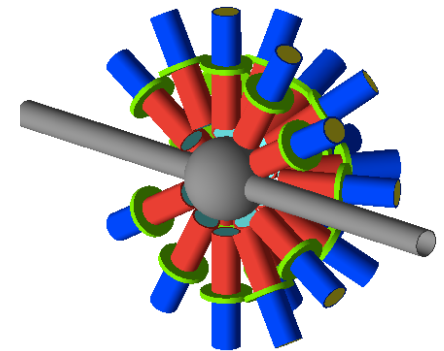
# ALBA – African $\text{LaBr}_3:\text{Ce}$ Array

- Composed of **23 large-volume  $\text{LaBr}_3:\text{Ce}$**   
iThemba LABS received 6 detectors + GAMKA consortium adding 17 detectors

GAMKA consortium:

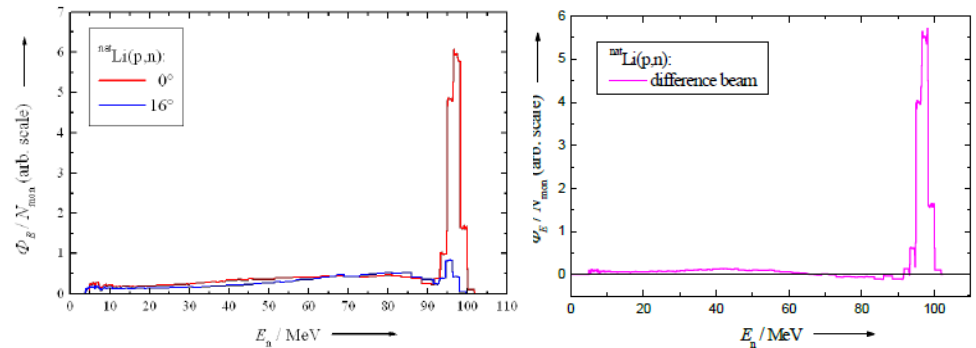
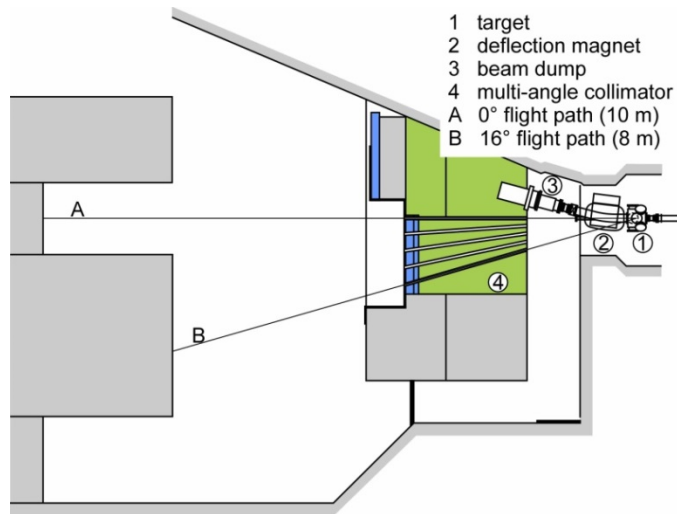


Efficiency at 13.2cm from target			
$\gamma$ -ray Energy (MeV)	1 $\text{LaBr}_3:\text{Ce}$ (%)	6 $\text{LaBr}_3:\text{Ce}$ (%)	20 $\text{LaBr}_3:\text{Ce}$ (%)
1	0.9	5.7	18.9
5	0.4	2.3	7.8
10	0.2	1.3	4.5



- Detectors mounted in flexible and interchangeable arrays. Possibility to use HPGe+LaBr.
- Stand-alone, coupled to K600 or with Silicon arrays

# Fast neutron beam facility



n tof spectra from 100 MeV p on Li, measured at neutron emission angles of 0° and 16°

- **Energies:** 30 to 200 MeV
- **Targets:**
  - Li, Be: quasi-monoenergetic
  - C: quasi-white ('grey')
- **Beam currents**
  - 3-5  $\mu\text{A}$  ( $E_p < 100$  MeV)
  - 300 nA ( $E_p = 200$  MeV)
- **Pulse selection:** 1/1 – 1/7
- **Time resolution:**  $\approx 1$  ns
- **Flight paths:**
  - 10 m (0°)
  - 8 m (16°)
- **Fluence rate** (1 mm Li):  $j \approx 1 \cdot 10^3 \text{ cm}^{-2} \mu\text{A}^{-1}$  at 10 m



**2018/19:** Reconstruction of the neutron vault to meet requirements for high-energy neutron metrology facility.

- Additional shielding
- Improved beam diagnostic
- Optimized beam stops
- Extended flight path at 16°

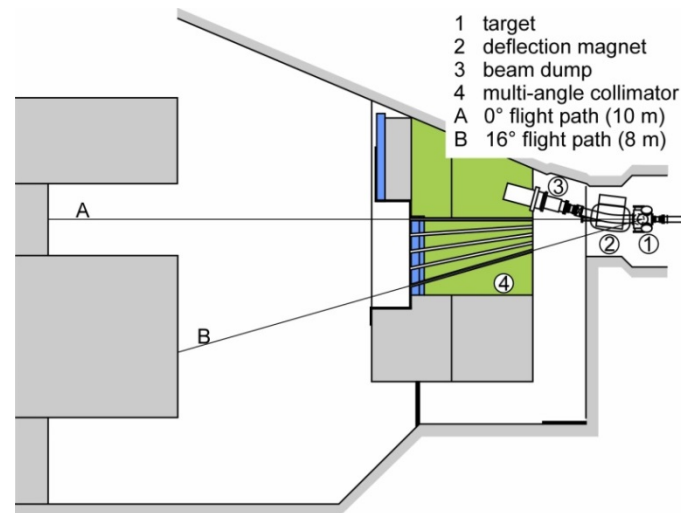
RS: P Maleka

# Workshop

## *Fast neutrons for the next decade and beyond*

To be held at iThemba LABS  
4-6 February 2019

SAC: Andy Buffler  
Frank Gusing  
Xavier Ledoux  
Wynand Louw  
Ralf Nolte  
Stephan Pomp  
Rene Reifarth  
Hiroshi Yashima  
Kai Zuber



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<https://indico.tlabs.ac.za/event/79/>



# $\beta$ -decay Analysis Tape Station

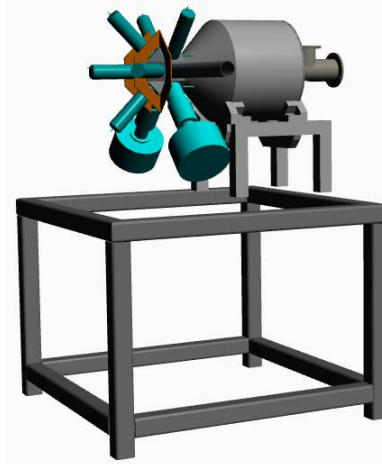


- The single-spool design has 50m of 12 mm wide mylar tape.
- maximum speed of  $1 \text{ ms}^{-1}$
- transporting activity 2.5 m from the implantation point to a measuring station
- SiLi for conversion electron detection
- Plastic scintillator
- Coupled to gamma-ray detectors.
- Commissioned 2018.

RS: R Bark

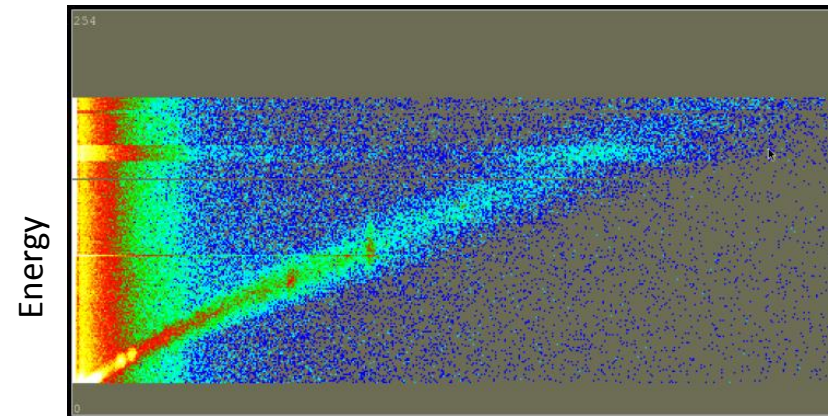


# Electron Spectrometer



$^{70}\text{Ge}(\alpha, \alpha')$

- Refurbished spectrometer, Siegbahn-Kleinheinz from Orsay.
- Field of  $B_{\text{max}} \sim 0.15\text{T}$ .
- Si(Li) detectors  $\sim 5\text{-}6\text{mm}$ .
- For: conversion electron spectroscopy  
Internal Pair Spectroscopy ( $E > 1.022$ )  
E0 decays
- Commissioned October 2018.

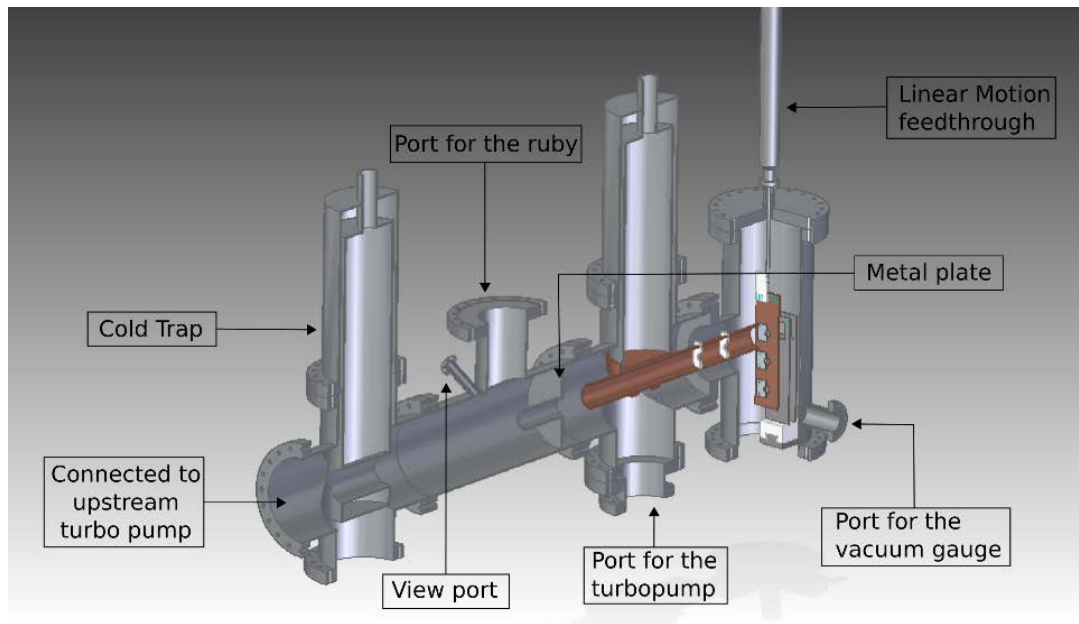


Magnetic Field

RS: P Jones

# DSAM setup

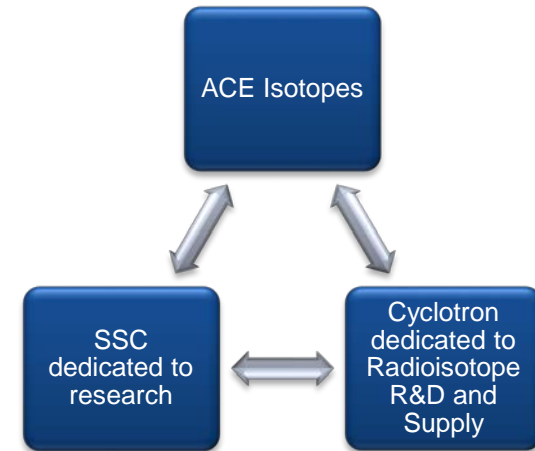
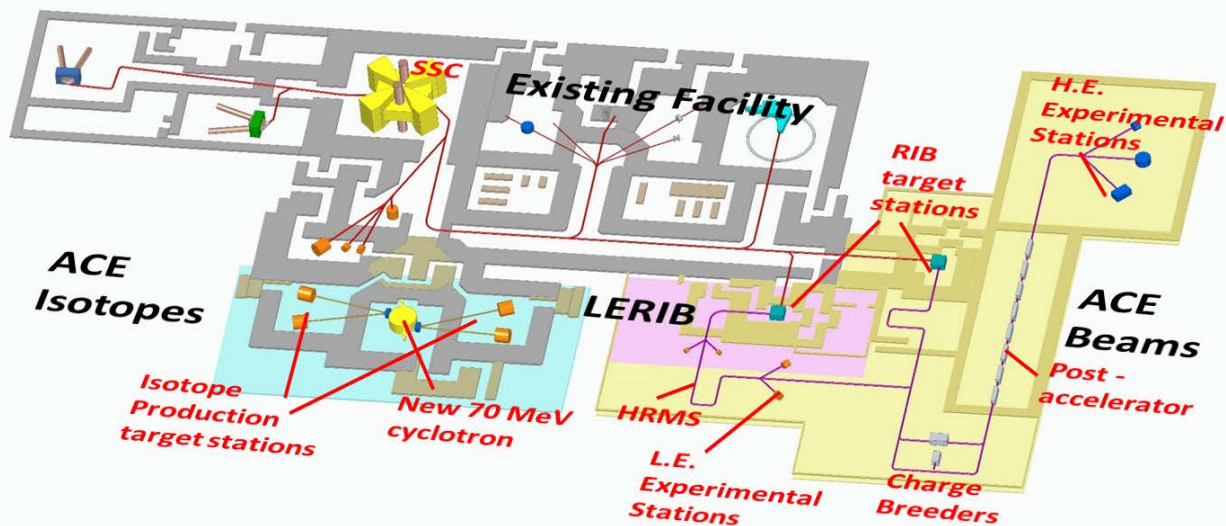
DSAM setup for half-lives of astrophysical important nuclei.



- A new DSAM lifetime measurement setup on the G-line.
- Expected to be very sensitive and will be able to measure lifetimes to  $\sim 10$ fs.
- First beam April 2018.
- Full commissioning Q1 2019

PI: S Triambak

# South African Isotope Facility (SAIF)



## Phase I: ACE Isotopes and LeRIB

- 70MeV cyclotron: dedicated to the production of isotopes.
- SSC: dedicated to beams for research (stable and LeRIB).
- Timeline - 4 years to operations

## Phase 2: ACE Beams

- SSC: dedicated to beams for research (stable and radioactive).
- Post-accelerated radioactive beams.
- Timeline - 8 years to operations

A male lion with a thick, golden-brown mane stands in a savanna landscape. The lion is looking towards the right of the frame. The background consists of dry, yellowish-brown grass and some green shrubs under a bright sky.

**ANPC**

# **African Nuclear Physics Conference**

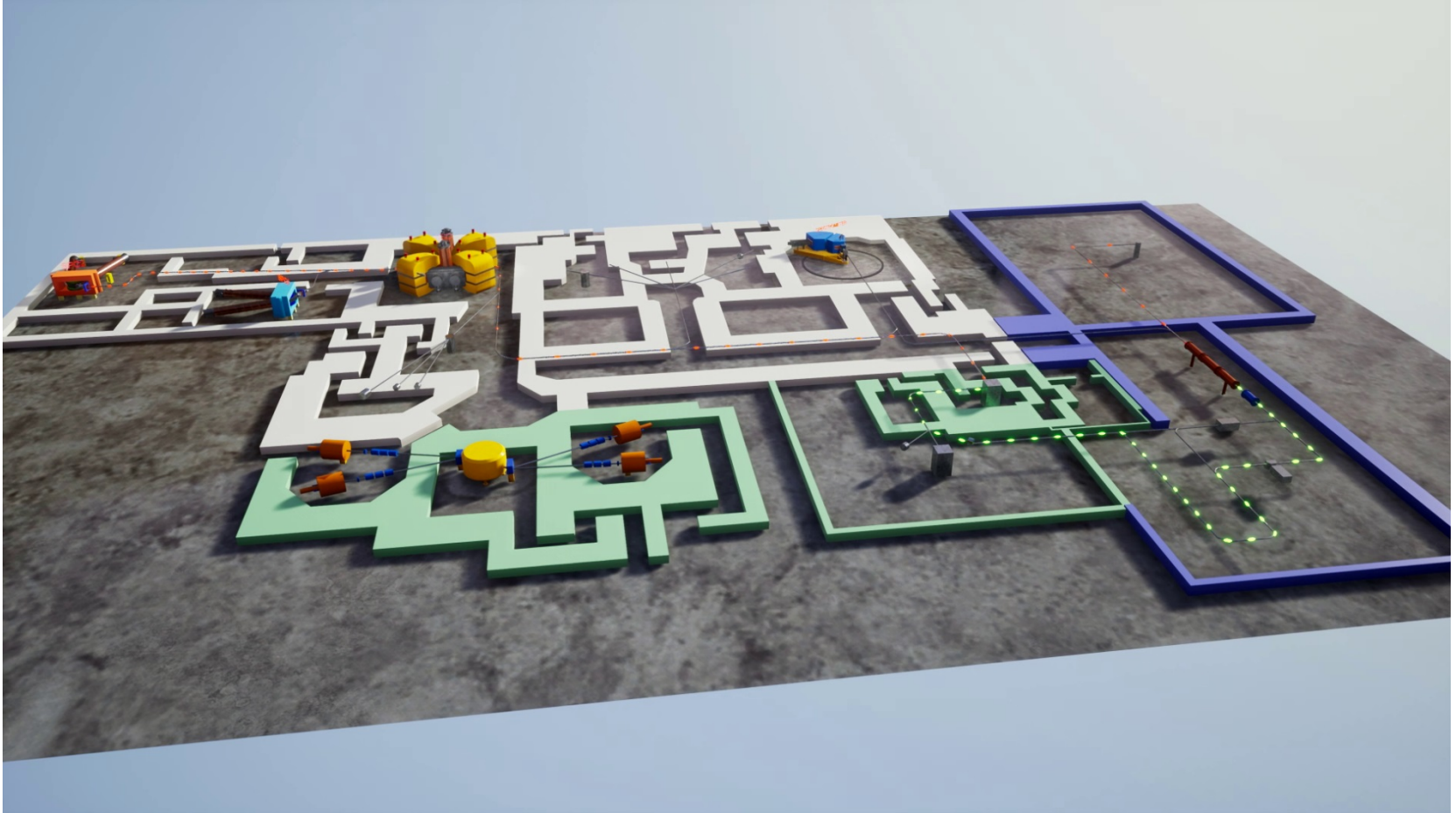
**Kruger2019**

**1-5 July 2019**

**Protea Hotel**

**Kruger Gate**

# Thank you!



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



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