

# Applications of Medical physics

*Zebon Z. VILAKAZI, iThemba LABS*

[director@tlabs.ac.za](mailto:director@tlabs.ac.za)

## *Note:*

The presentation has a bias on South Africa: Apologies for any omissions – largely a function of lack of detailed knowledge of the continental landscape

# Applications

- Medical Applications
  - Radiotherapy for cancer
    - Kill cancer cells.
    - Used for 100 years but can be improved by better delivery and dosimetry
    - Heavy ion beams can give more localised energy deposition.
  - Medical Imaging
    - MRI (Nuclear magnetic resonance)
    - X-rays (better detectors → lower doses)
    - PET
    - Tc99(m)
    - Many others....
- Other Applications
  - Radioactive Dating
    - $C^{14}/C^{12}$  gives ages for dead plants/animals/people.
    - Rb/Sr gives age of earth as 4.5 Gyr.
    - $O^{16}/O^{18}$  in  $H_2O$  in ice gives temperature
    - $U^{238}/Th^{232}$  in stars gives ages of galaxies
  - Element analysis
    - Forensic (eg date As in hair).
    - Biology (eg elements in blood cells)
    - Archaeology (eg provenance via isotope ratios).

# Nuclear Facilities in Africa



Comena, Algiers  
Centre national  
pour la Recherche  
Nucleiare:  
CRNA 3.75MV-VDG

Inshas Cyclotron  
Facility (ICF),  
Cairo; Russian type  
MGC-20 AVF  
cyclotron (20 MeV).

Centre for Energy  
Research  
development  
(CERD); Ife,  
Nigeria



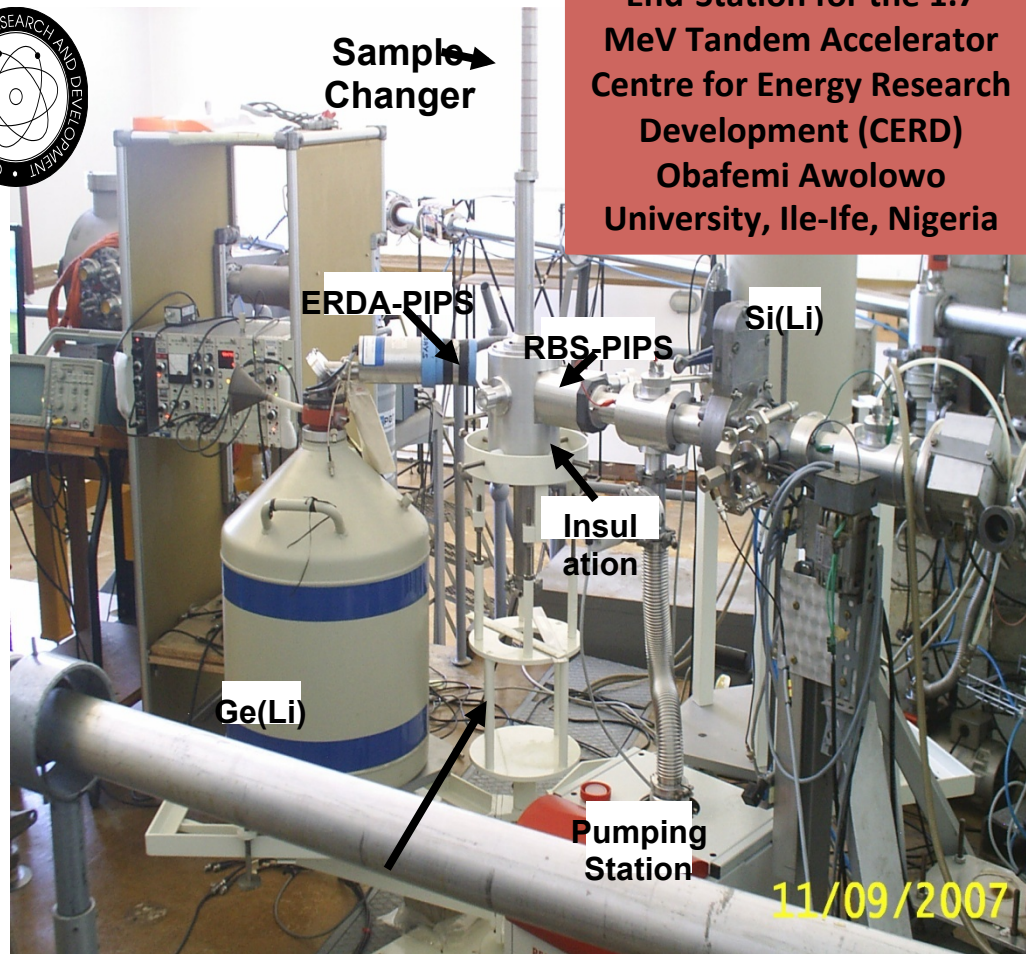
# Collaboration with Nigeria



Centre for Energy Research & Development Pelletron Tandem Accelerator Other Names: CERD 1.7 Pelletron  
Location: CERD-Ife Ife (Osun State)  
Subordinate to: Nigerian National Nuclear Commission  
Size: 1.7MV  
Status: Operational + work carried out

*End station commissioned by the iThemba LABS team.*

**Ion Beam Analysis (IBA) End-Station for the 1.7 MeV Tandem Accelerator  
Centre for Energy Research Development (CERD)  
Obafemi Awolowo University, Ile-Ife, Nigeria**



# Beginning of Nuclear Research in SA

- 1948 – 1950: At CSIR, newly appointed head of the Nuclear Physics Division sent to the Nobel Institute in Stockholm to do Nuclear Physics research with a classical cyclotron.
- 1950: Decision to design and build a 16 MeV deuteron classical cyclotron at the Nuclear Physics Division, CSIR
- Southern University Nuclear Institute (SUNI) established jointly by Universities of Stellenbosch & Cape Town [1964]
- Pioneering Neutrino experiments (led by F Riennes) in the mines of Johannesburg (*circa*: 1966)
- JPF Sellschop establishes a research accelerator at University of Witwatersrand, Johannesburg [1972]

**CSIR: Council for Scientific and Industrial Research**

# Research Facilities in South Africa



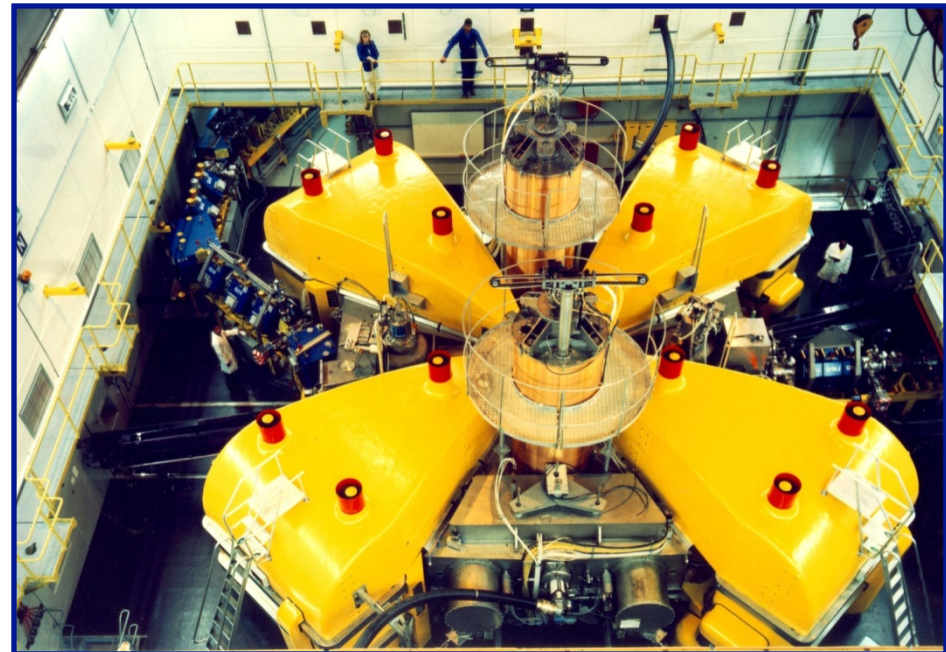
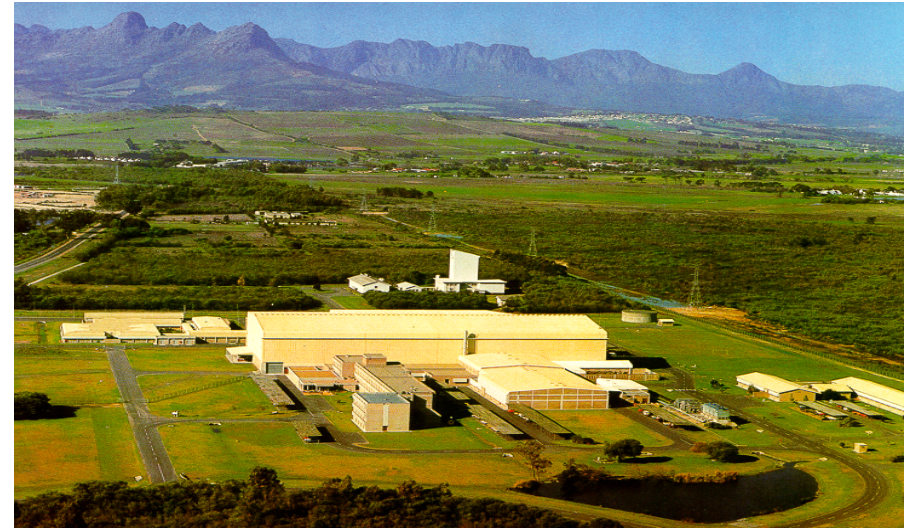


# About iThemba LABS

- iThemba L(aboratory) for A(ccelerator)-B(ased) S(ciences) is a multi-disciplinary research centre, operated by the NRF (National Research Foundation). It provides accelerator and ancillary facilities for:

- ✦ Research and training in the physical, biomedical and material sciences
- ✦ Treatment of cancer patients with energetic neutrons and protons and related research
- ✦ Production of radioisotopes and radiopharmaceuticals for use in nuclear medicine, research and industry and related research

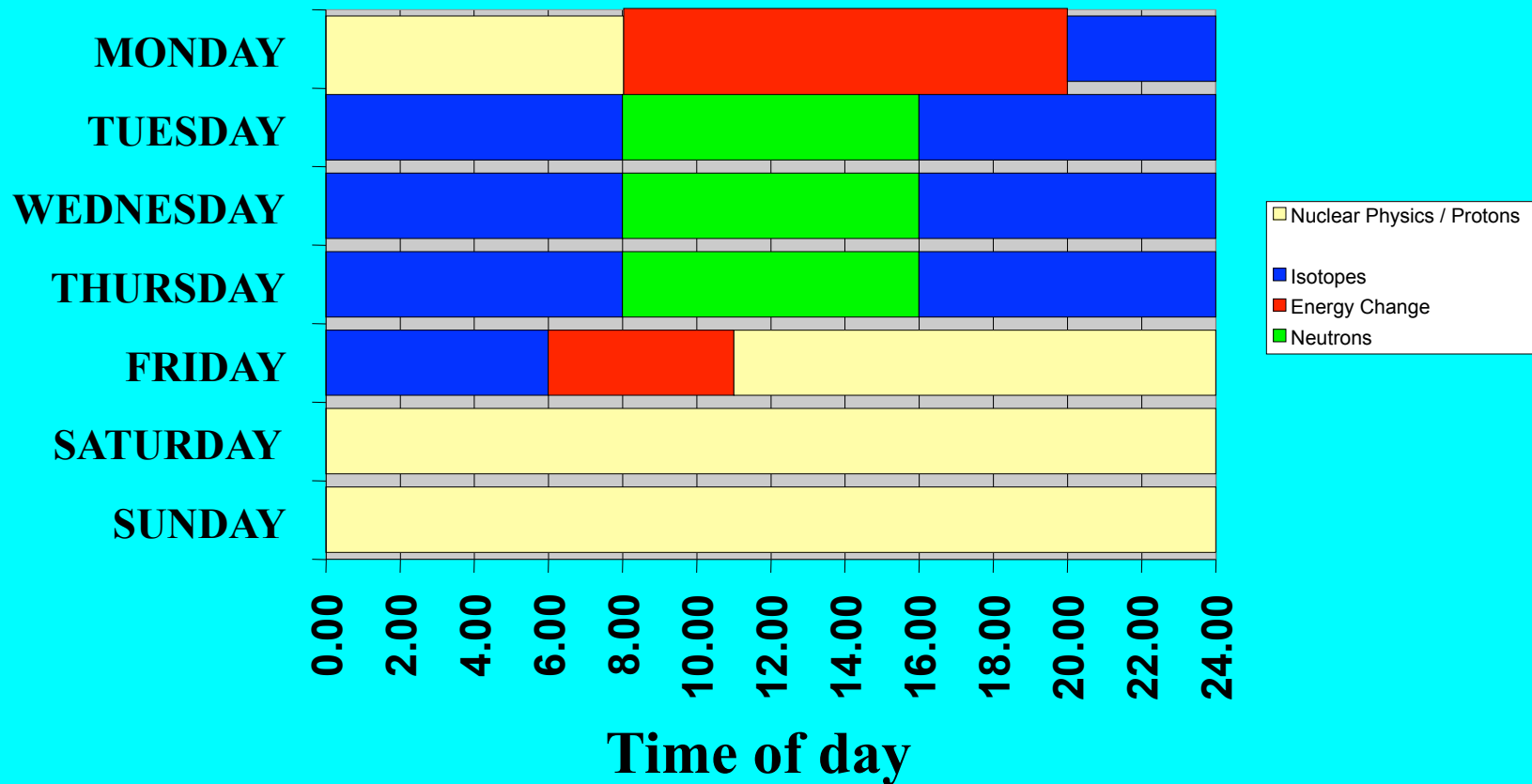
The largest accelerator complex in the Southern Hemisphere



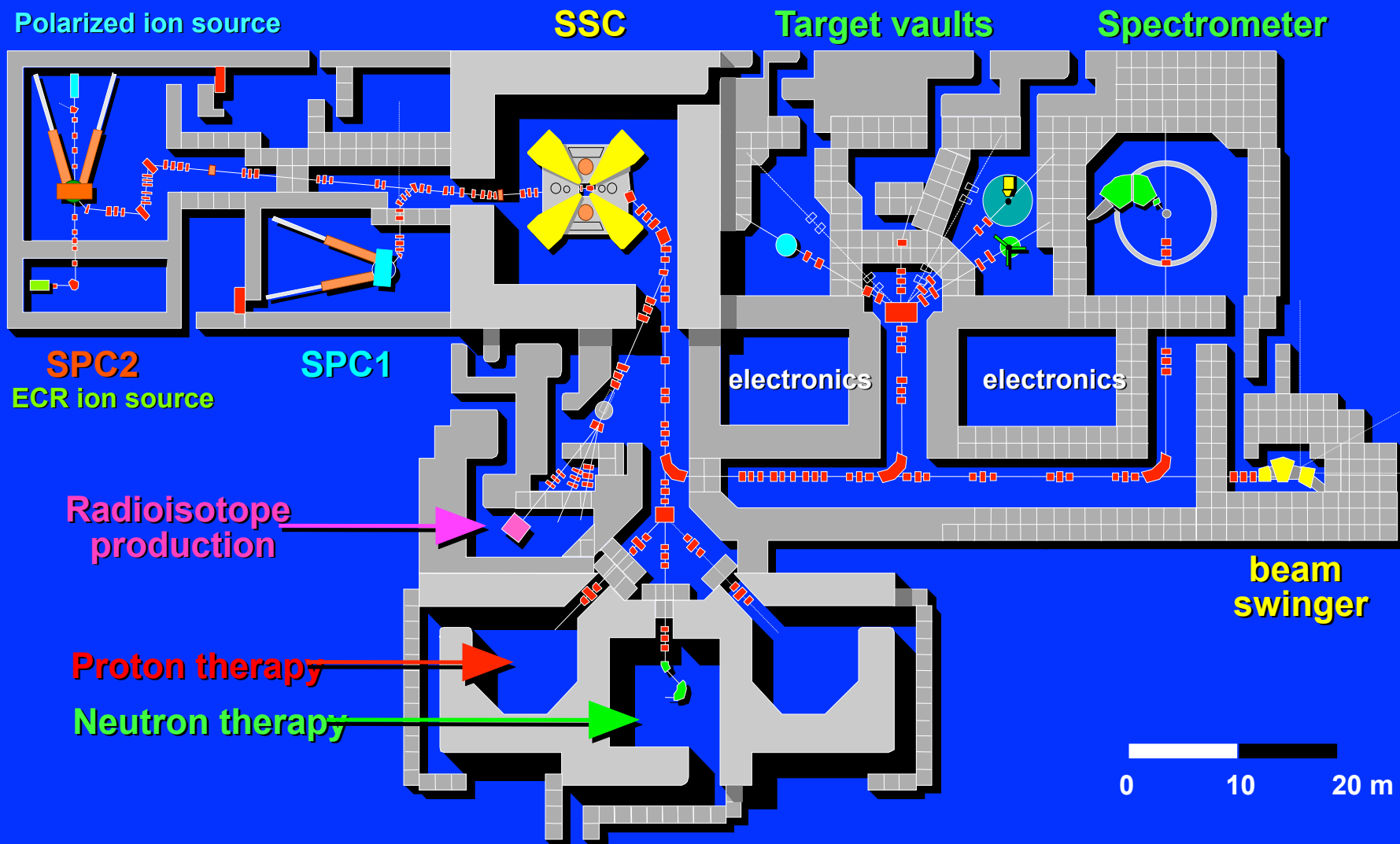




# CYCLOTRON OPERATING SCHEDULE



# Separated-Sector Cyclotron Facility



# Radio nuclides

- Currently, iThemba LABS produces weekly the medical radionuclides  $^{67}\text{Ga}$ ,  $^{123}\text{I}$  and  $^{81}\text{Rb}$ .
- $^{67}\text{Ga}$  and  $^{123}\text{I}$  are used to prepare radiopharmaceuticals for the local users.
- $^{81}\text{Rb}$  is used to manufacture the  $^{81}\text{Rb}/^{81\text{m}}\text{Kr}$  generator.
- $^{82}\text{Sr}$  is produced for use in medical generators to obtain the PET radionuclide  $^{82}\text{Rb}$ .
- $^{22}\text{Na}$  is produced to manufacture positron sources.
  - Export to CERN (anti- H experiment)
- Close to 60 local users in nuclear medicine

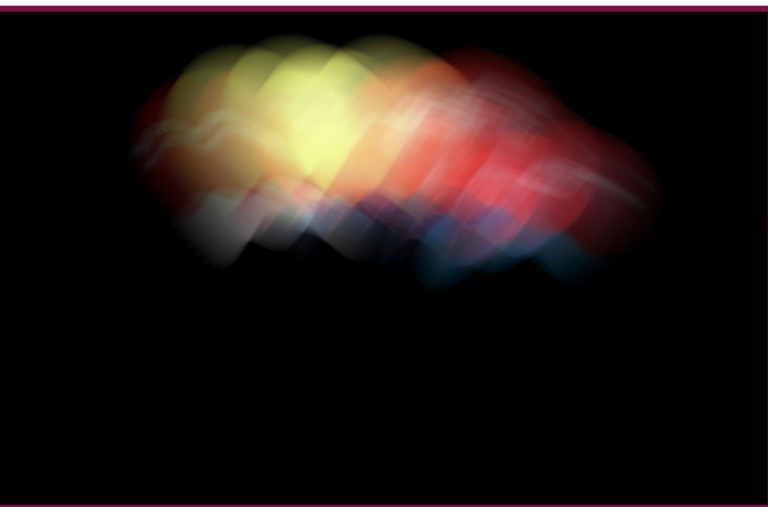
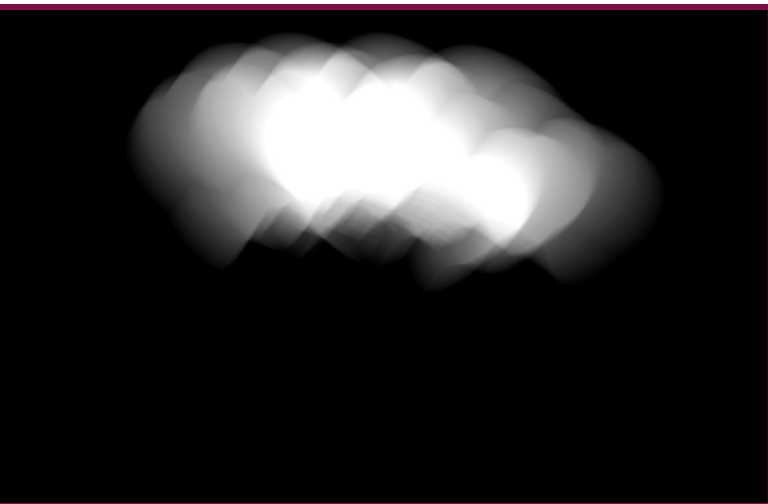




# Supply for Nuclear Medicine



# NU-Clear Medicine: PET/CT



**PET/CT Road Map to Personalized Molecular Medicine**



# iThemba Particle Therapy Centre [iTPTC]



**iThemba  
LABS**  
Laboratory for Accelerator  
Based Sciences

*A silent crisis in cancer treatment persists in developing countries and is intensifying every year. At least 50 to 60 percent of cancer victims can benefit from radiotherapy that destroys numerous tumours, but most developing countries do not have enough radiotherapy machines or sufficient numbers of specialised doctors and other health care professionals.*

**Mohamed El Baradei, Former IAEA Director General:  
“A Silent Crisis”, IAEA Report (September 2003)**

# Status of Cancer Treatment in Developing Countries



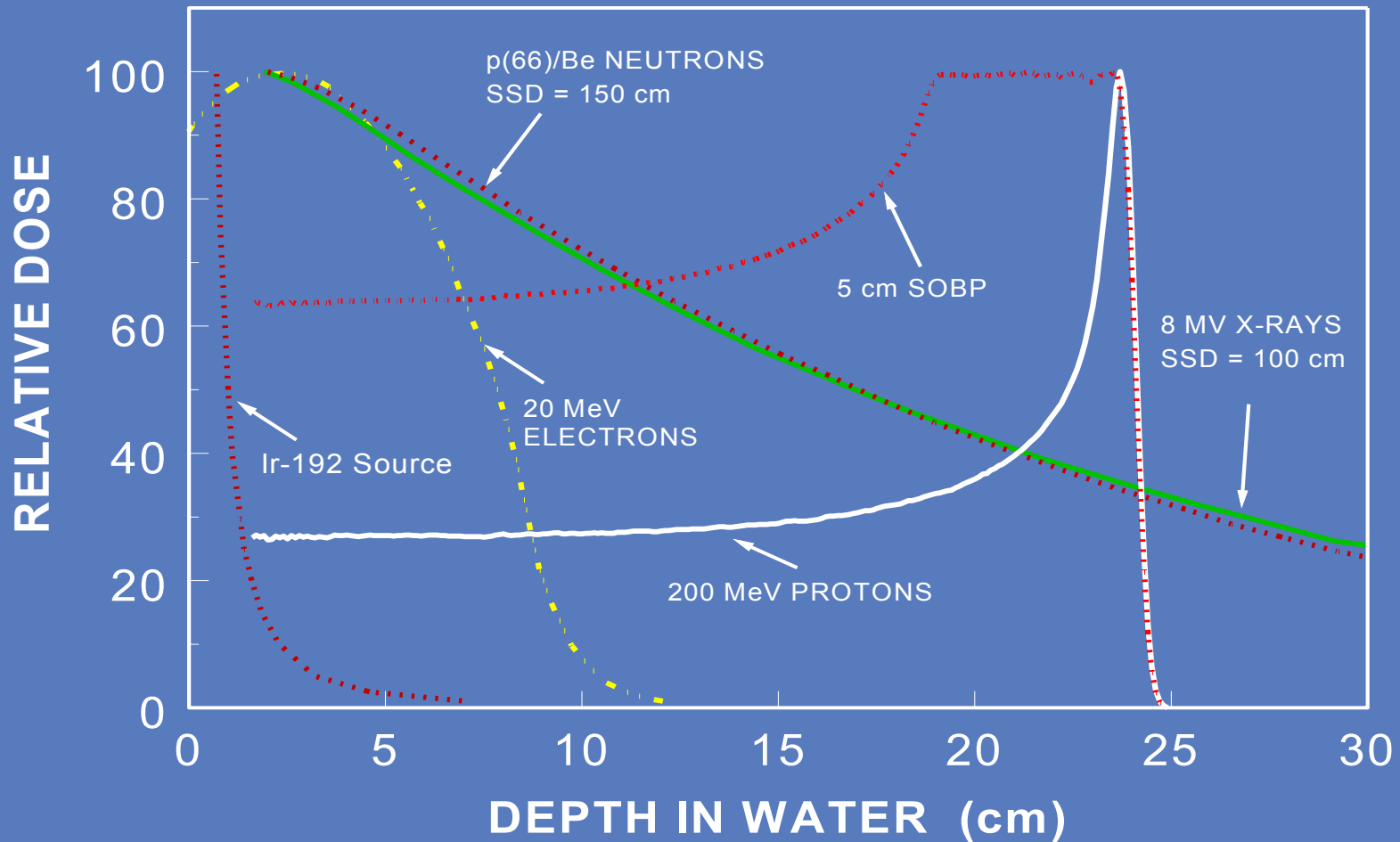
- **Developing countries comprise 85% of world population but have only 1/3 of radiotherapy facilities.**
- **Currently, there are 2200 radiotherapy machines, require 5000 today and 10000 by 2015.**
- **One machine for several million people compared to 1 per 250 000 for developed countries.**
- **WHO predicts doubling of cancer cases in developing world over next 10 years (5 million to 10 million)**
- **At least US\$2,5 billion is needed over next 10 years to provide adequate treatment facilities, 50% for training and development of personnel.**

# iThemba Particle Therapy Centre [iTPTC]

## Physical Principles

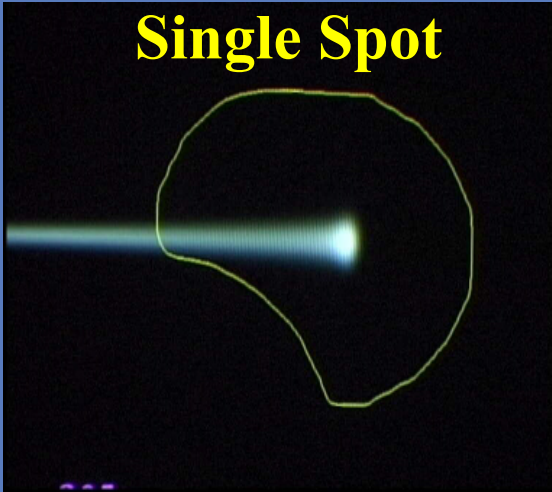


**iThemba  
LABS**  
Laboratory for Accelerator  
Based Sciences

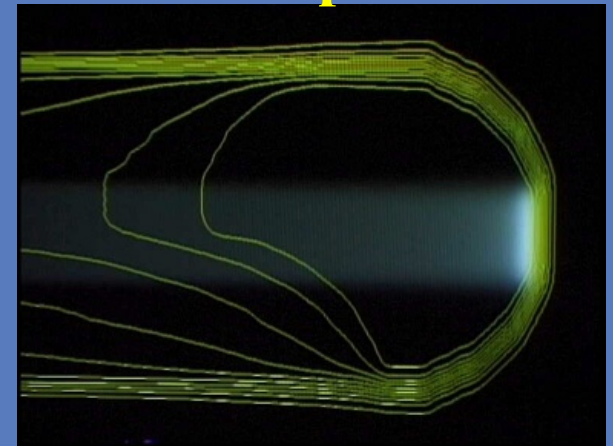


## Spot Scanning Principle

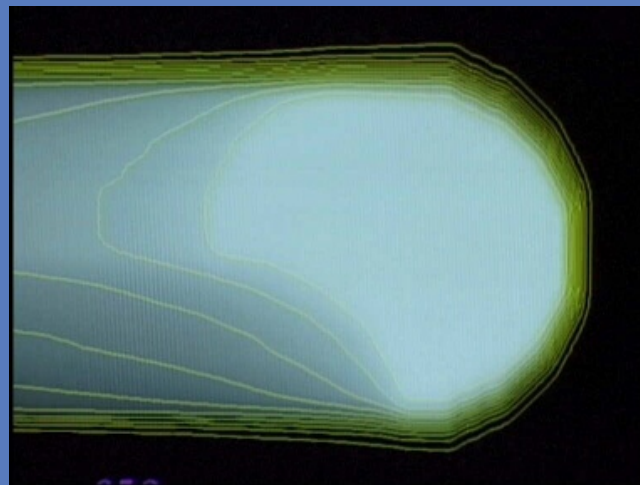
**Single Spot**



**Few Spots**



**Final Dose  
Distribution**



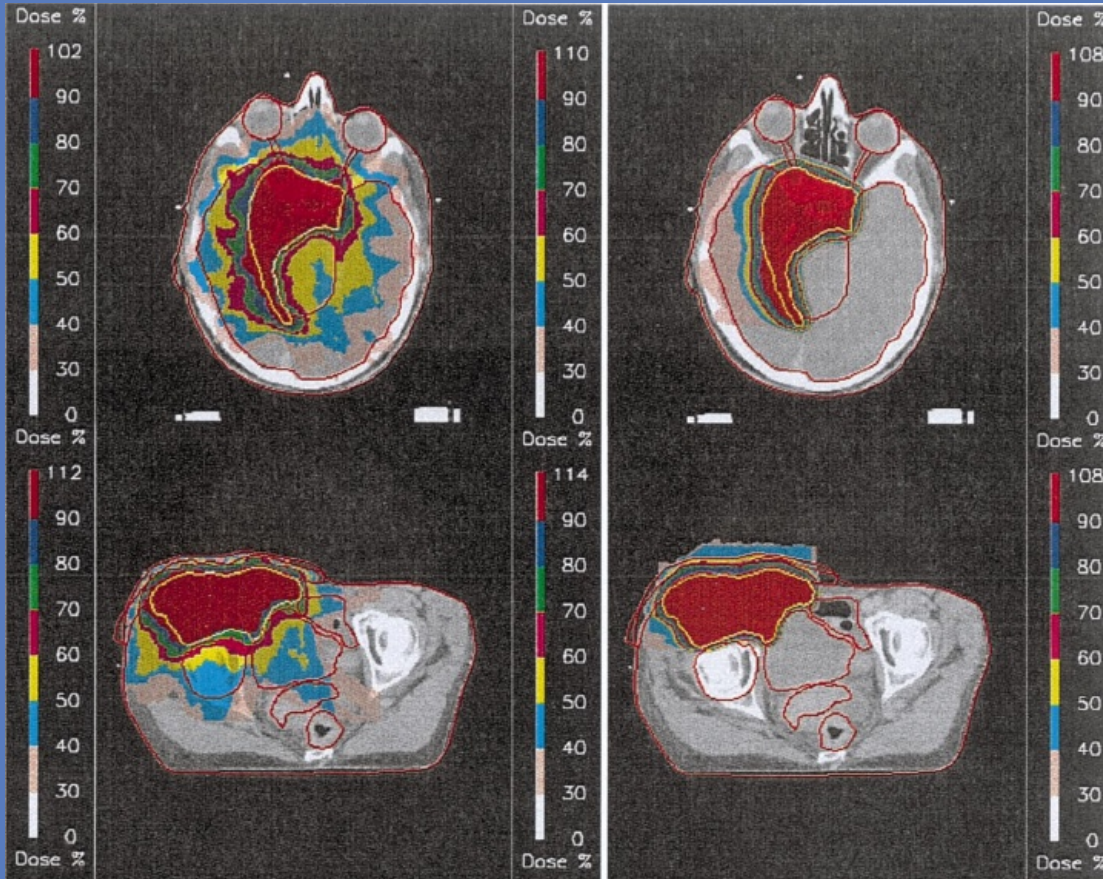
# iThemba Particle Therapy Centre [iTPTC]

## Protons vs Modern X-rays IMXT



**iThemba  
LABS**  
Laboratory for Accelerator  
Based Sciences

1



(1) Meningioma, (2) Malignant melanoma

Left – IMXT, 9 fields, Right – Proton Spot Scanning, 2 fields

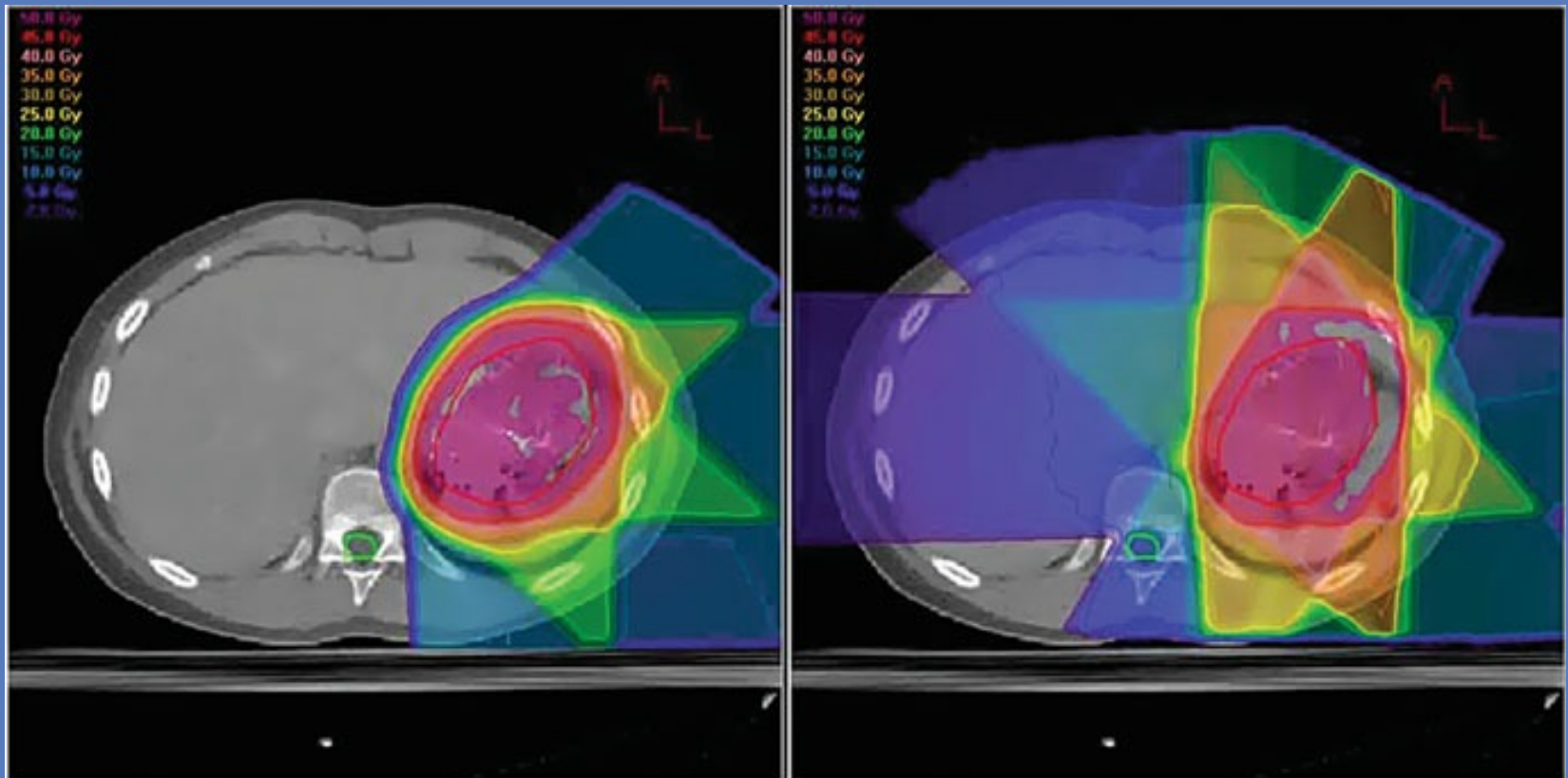


# iThemba Particle Therapy Centre [iTPTC]

## Protons vs Modern X-rays - IMXT



**iThemba  
LABS**  
Laboratory for Accelerator  
Based Sciences



Liver Cancer

Left – Passive scattered proton, 3 fields,

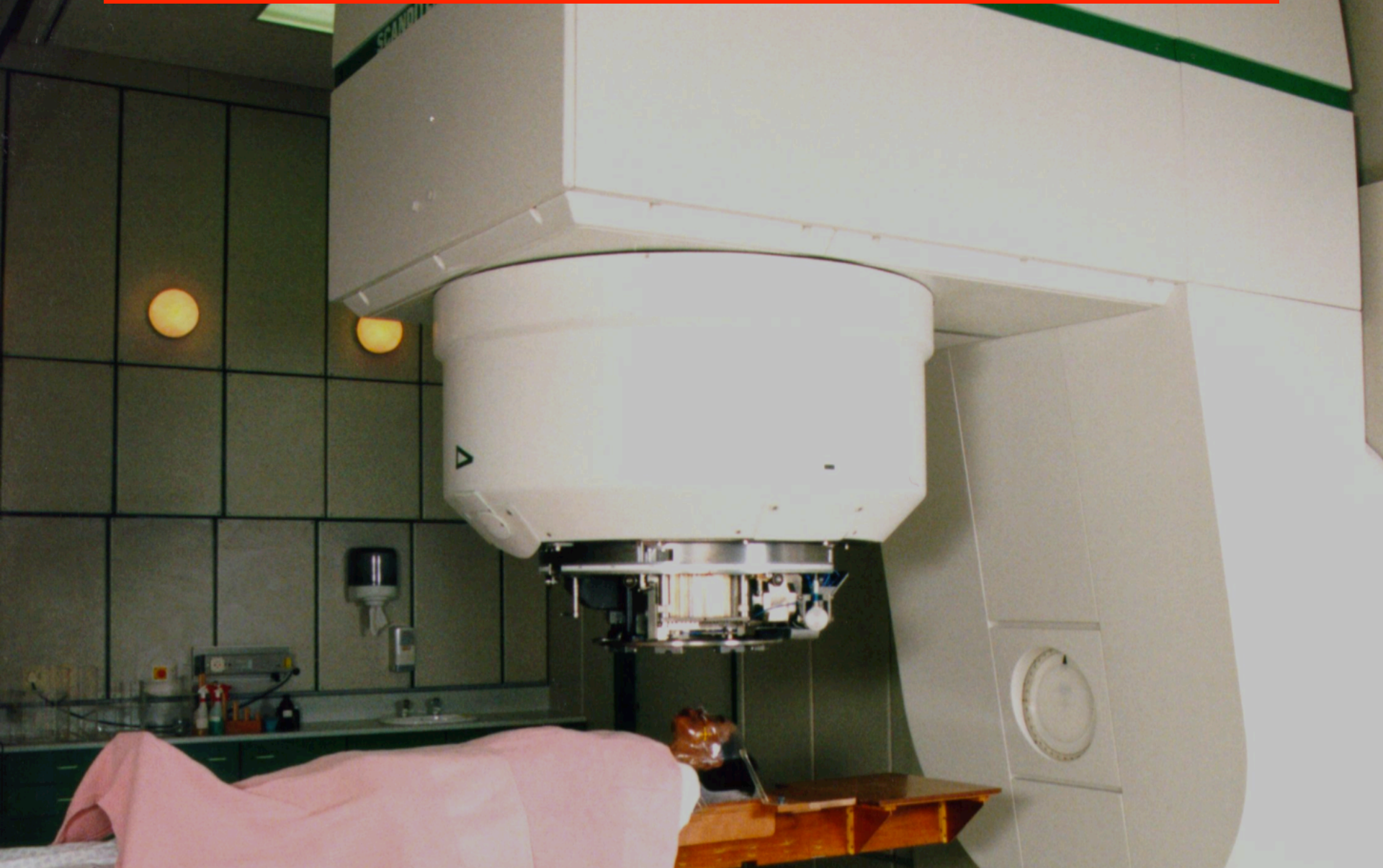
Right – IMXT, 6 fields



# Particle Therapy Programme

- **Neutron Therapy at 66MeV (commenced: 1988)**
- **Proton Therapy at 200MeV (commenced: 1993)**
  - **Number of Patients Treated:**
    - Neutrons: > 1 460**
    - Protons: > 500**
  - **Various Types of Cancer Treated:**
    - Protons: Brain Tumours; Acoustic Neuroma; Pillsbury Adenoma; Eye Tumour.**
    - Neutrons: Breast; Salivary Glands  
Head, Neck Carcinomas;  
Malignant Melanomas.**

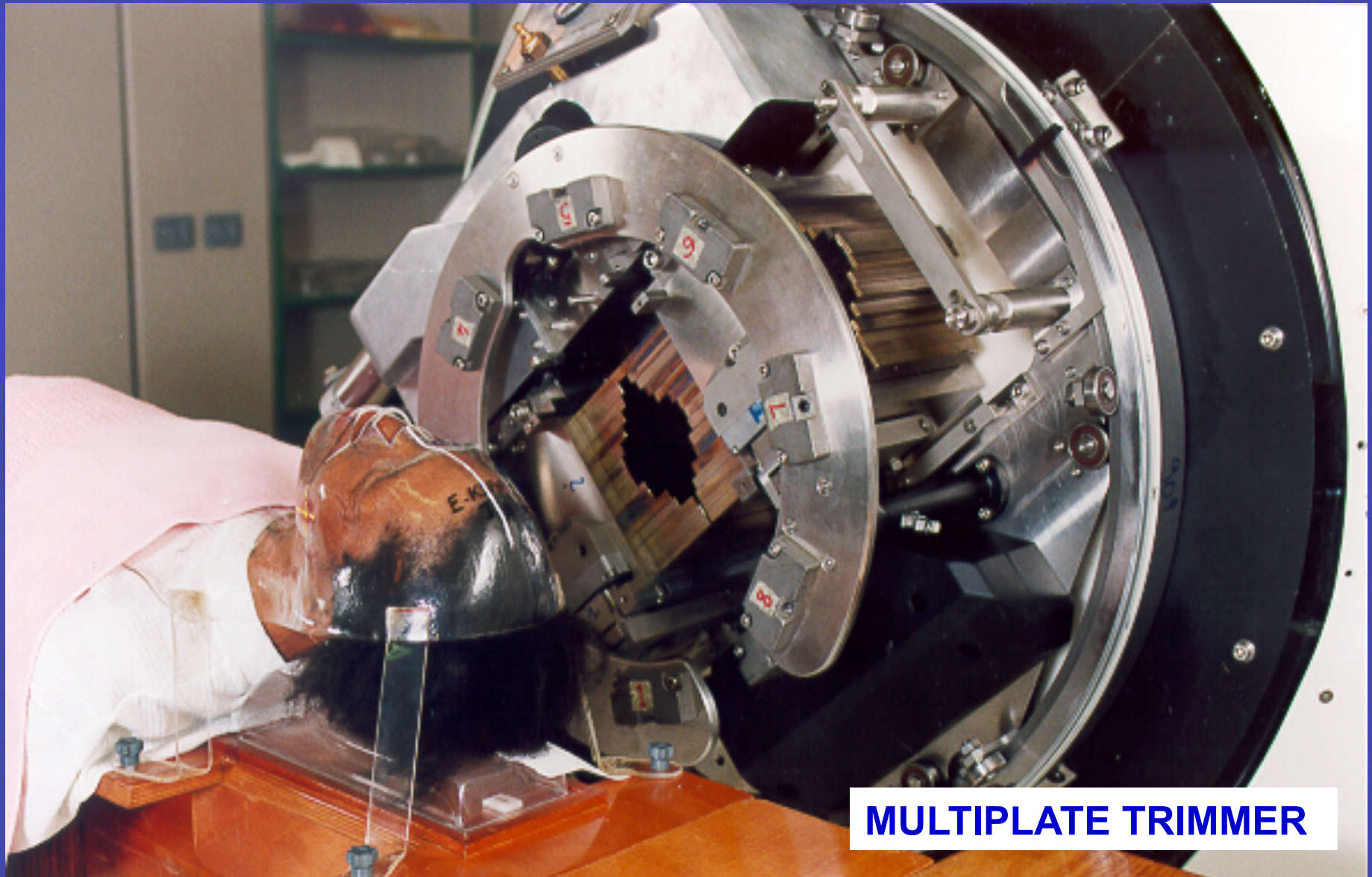
# Neutron Therapy



# Early Neutron patient







**MULTIPLATE TRIMMER**

# iThemba Particle Therapy Centre [iTPTC] Neutron Therapy Results



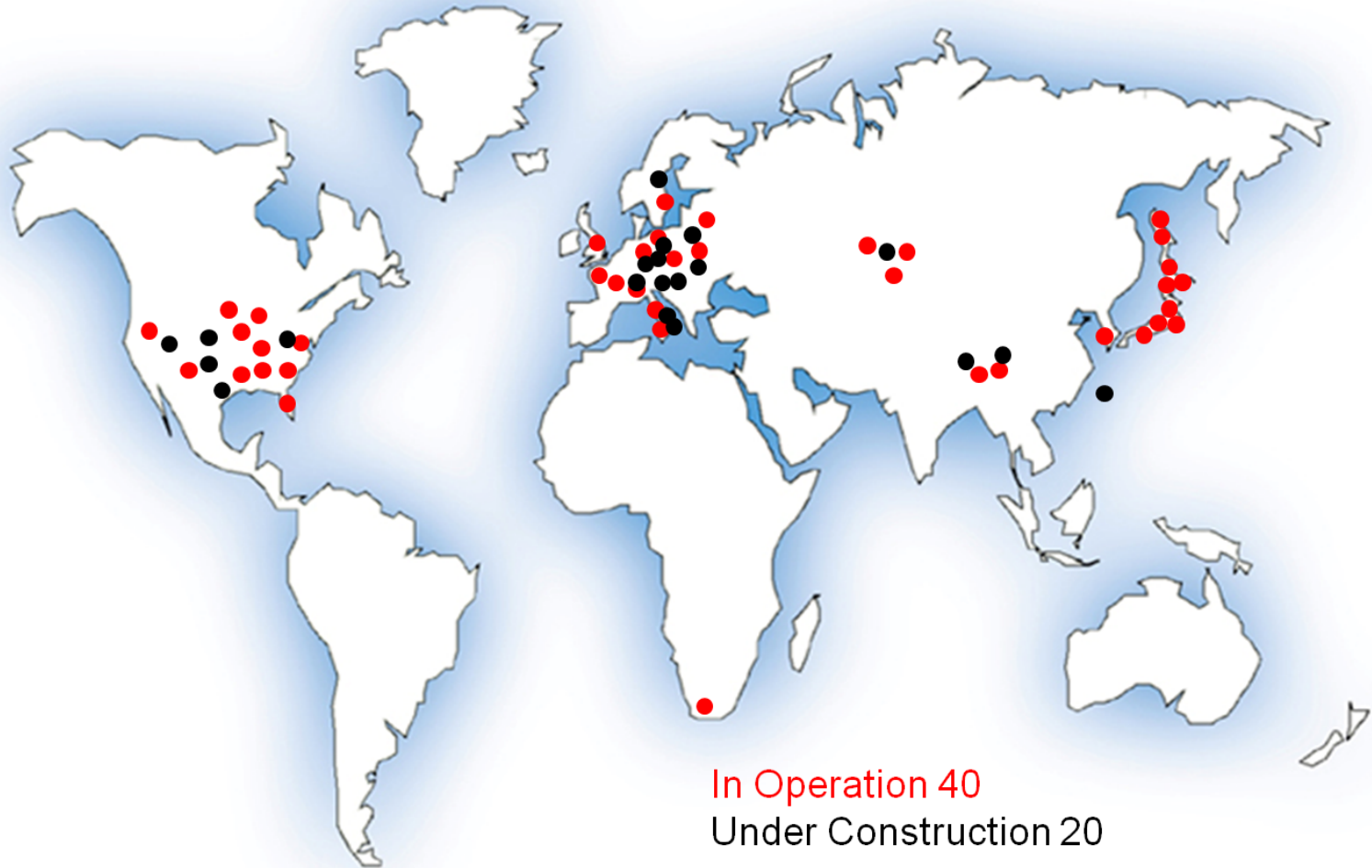
Before Neutron Therapy



After Neutron Therapy



# iThemba Particle Therapy Centre [iTPTC] Proton Therapy Centre's



# Current Therapy Programme : Resources

## Personnel (Full time) : 42

- Research staff 4
- Physicists : Operations 2
- Technical (Mechanical, E&IT) 5
- Radiographers 6
- Medical (Oncologist, Hospital Manager, Dietician + nurses) 10
- Support staff 15

## Financial (2010/11)

Salaries (MR)	Operating (MR)	Capital (MR)	TOTAL (MR)
10,6	3,5	0,4	14,5 *

\*Cost saving without neutron therapy 2 MR

# iThemba LABS : Radiation Therapy



**27 bed on-site hospital**

**Proton Therapy : 4X4 Weeks/Year** (April 2009)

Monday and Friday

**Neutron Therapy: Tuesday-Thursday**

**Number of patients treated:**

	2005/ 06	2006/ 07	2007/ 08	2008/ 09	2009/ 10	Cum.
<b>Proton</b>	10	6	9	3	3	508
<b>Neutron</b>	71	70	58	65	54	1659



# iThemba Particle Therapy Centre [iTPTC]



## Hope for a new generation

- Education of Scientists
- Training for medical professionals
- Partnerships with national universities and clinics
- Evolution of the healthcare service in Africa



**= Hope for the Future**

- Through the development of an integrated cancer center
- In collaboration with private partners
- Focus on sustainable social advancement for the country and Africa
- Sharing and spreading knowledge

# **iThemba Particle Therapy Centre [iTPTC]**

## **Primary Objective**



### ➤ **PARTICLE THERAPY CENTRE**

**Proton Therapy**

**Neutron Therapy**

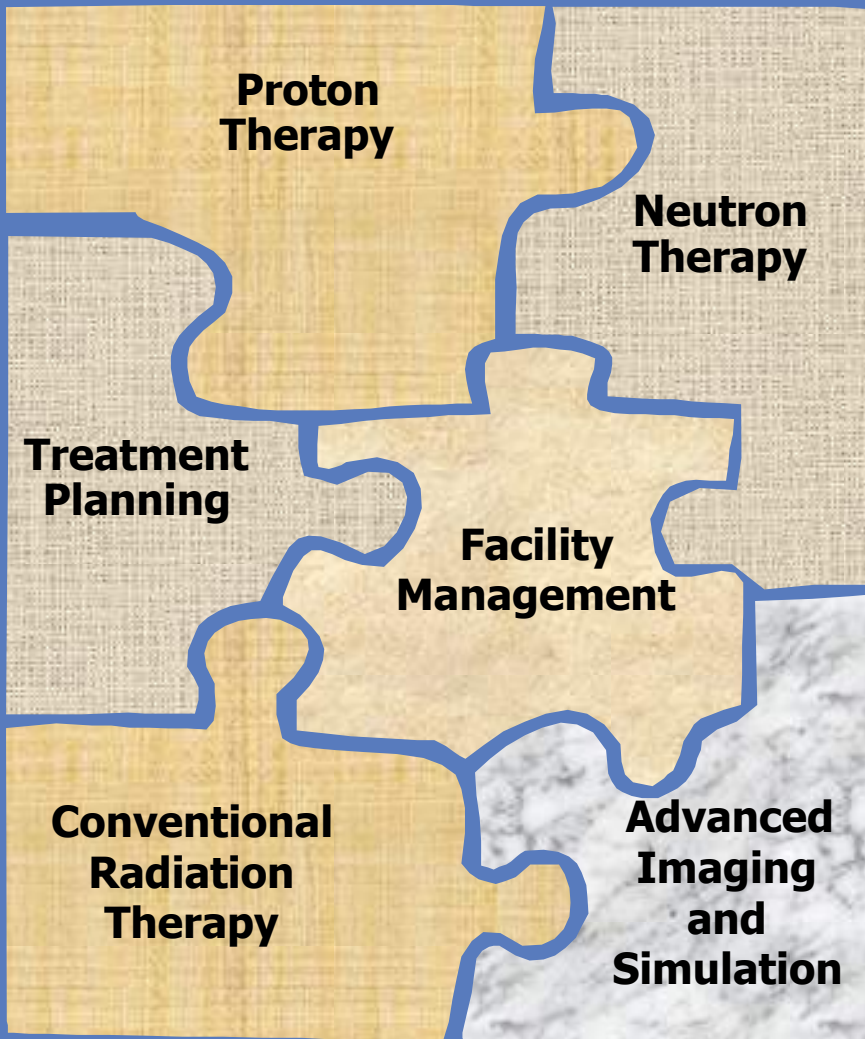
**CT MRI Imaging and Diagnostic Facilities including PET**

**30 bed hospital + patient support facility**

### ➤ **ESTABLISH WORLD-CLASS Treatment,**

**Research and Training Facilities for South African and African Communities and National and International Partners**

# iTPTC : An Integrated Cancer Centre



*« We believe that any PT facility should be part of a comprehensive oncology centre that provides, extensive diagnostic imaging, photon, neutron, proton therapy and as well as other cancer management services... »*

**Varian**

# **iThemba Particle Therapy Centre [iTPTC]**



## **Why with iThemba LABS?**

- **iThemba LABS**
  - Core of skills and experience
  - World renowned track record
  - Existing Infrastructure
  - World public credibility
  - Technical back-up on site
  - Ambulatory Patients – near CT airport
  - Beautiful, convenient, and stress free location
  
- **External**
  - iThemba LABS Networking → access to
  - Advances in Accelerator & Computer technologies
  - Globalization of Health Care
  - Advances in Oncology and Imaging

# **Collateral Benefits (General)**



- **Builds skills, capacity and economy**
- **International Centre of Health Excellence**
- **Complement other modalities in RSA and SADEC, plus helps grow “Health Tourism” generally**
- **Attracts International Researchers and Innovators**
- **Unique facilities will keep the iTPTC at cutting edge of clinical and technological research for at least 20 years**
- **Accelerates Transformation and wider applications of RT.**
- **Builds Public-Private Partnership and inward investment**
- **Builds Reputation and Self-belief of Africa/African**

# **Collateral Benefits (South African Health Sector)**



- **World class facility for education and training of radiation medicine personnel.**
  - **±100 medical physicists, radiographers and oncologists over a 7 year cycle.**
  - **In-service training at international proton therapy centres (MGH, Florida, Indiana)**
  - **Close collaboration with local medical schools**
- **Proactive treatment of cancer, especially for previously disadvantaged groups.**
- **Development of internationally accepted clinical protocols with world renown centres (e.g. MGH)**
- **Increase cancer survival rates in South Africa.**

# Cancer : A major problem world wide



- **World Health Organization (*Report 2008*)**
  - **11 Million new cases annually**
  - **By 2030 : sharp increase to 21 Million**
  - **Mortality rate to increase from 7,6m to 13,2 m in 2030**
  - **1 : 4 (men) and 1 : 6 (women) will develop cancer in South Africa**
- **Africa: Increase in cancer of 50%-100% in next 5-10 years**
- **South Africa : est. 150 000 new cases annually**
- **> 50% of cancer patients world-wide are treated with radiotherapy**



# **iThemba Particle Therapy Centre [iTPTC]**

## **Key Operational Assumptions**



- **3 year implementation period, operational capacity achieved in year 7**
- **3 Treatment Vaults: 2 Gantries, 1 fixed beam line**
- **Current 2 vaults for future expansion**
- **>1000 proton patients annually**
- **20 fractions/treatment – 20 minutes/fraction**
- **5 days/week, 14 hours/day**
- **82 additional personnel**
  - 4 oncologists
  - 6 Medical Physicists
  - 31 Radiographers
  - 15 Nurses  
(2 shifts/Day)



# iThemba Particle Therapy Centre [iTPTC]

## Proposed Organisational Interfaces

