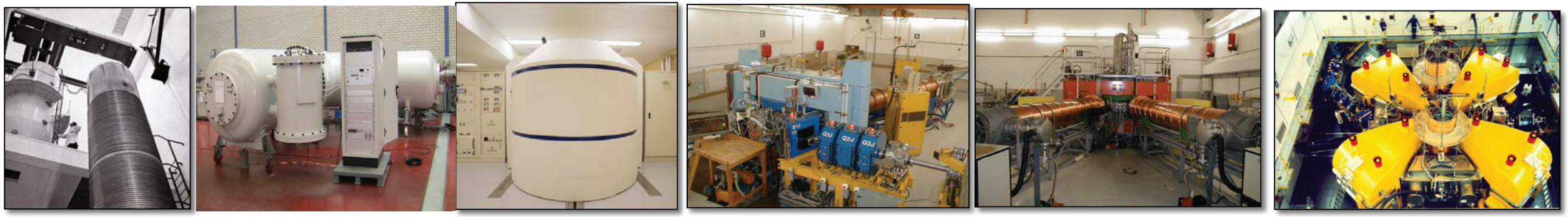


A RADIOACTIVE ION BEAM AND ISOTOPE PRODUCTION FACILITY FOR ITHEMBA LABS

J. L. CONRADIE, L. S. ANTHONY, S. BAARD, R. A. BARK, A. H. BARNARD, P. BEUKES, A.H. BOTHA, J. I. BROODRYK, J. C. CORNELL, J. G. DE VILLIERS, H. DU PLESSIS, W. DUCKITT, D. T. FOURIE, P. GARDINER, I. H. KOHLER, C. LUSSI, R. H. MCALISTER, J. MIRA, H. W. MOSTERT, C. NAIDOO, F. NEMULODI, M. SAKILDIEN, G. F. STEYN, R. W. THOMAE, M. J. VAN NIEKERK, P. A. VAN SCHALKWYK, ITHEMBA LABS, SOMERSET WEST, SOUTH AFRICA

A. ANDRIGHETTO, A. MONETTI, G. PRETE, M. ROSSIGNOLI, INFN, LABORATORI NAZIONALI DI LEGNARO, VIALE DELL'UNIVERSITÀ, 2 - 35030 LEGNARO, PADOVA, ITALY

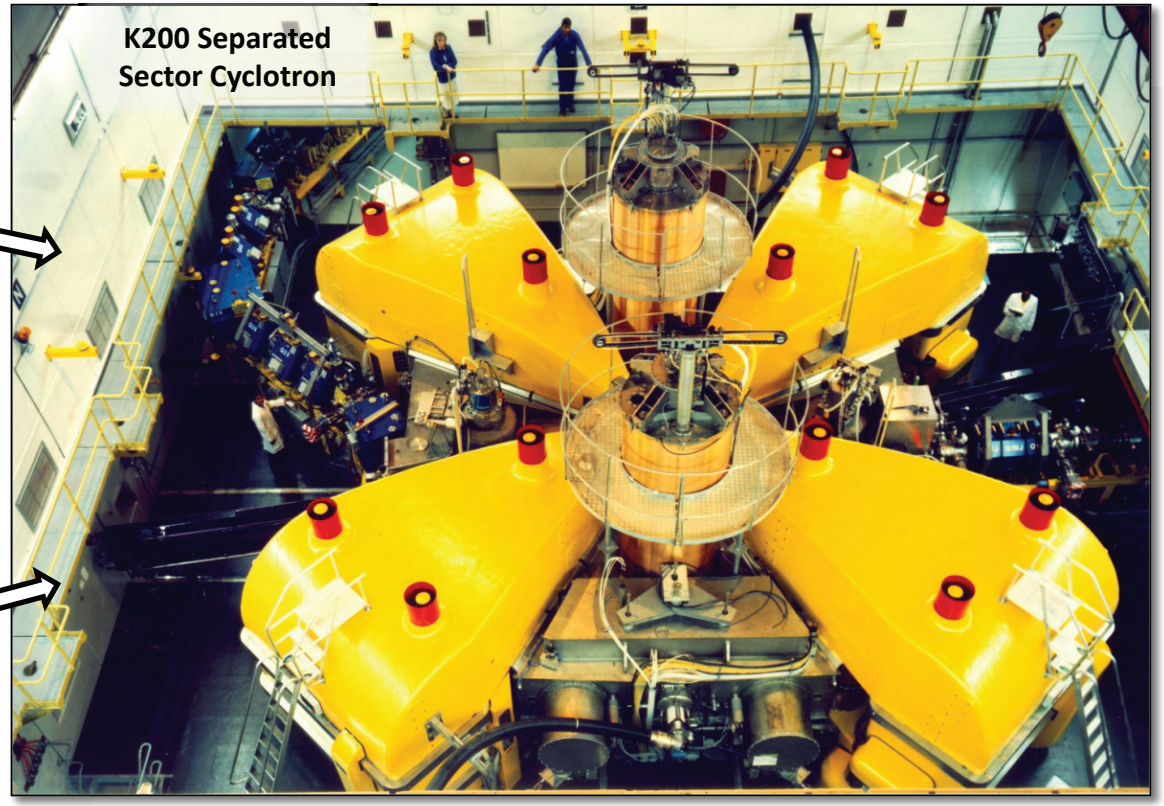
Cape Town – “Mother City”

Officially founded on 6 April 1652

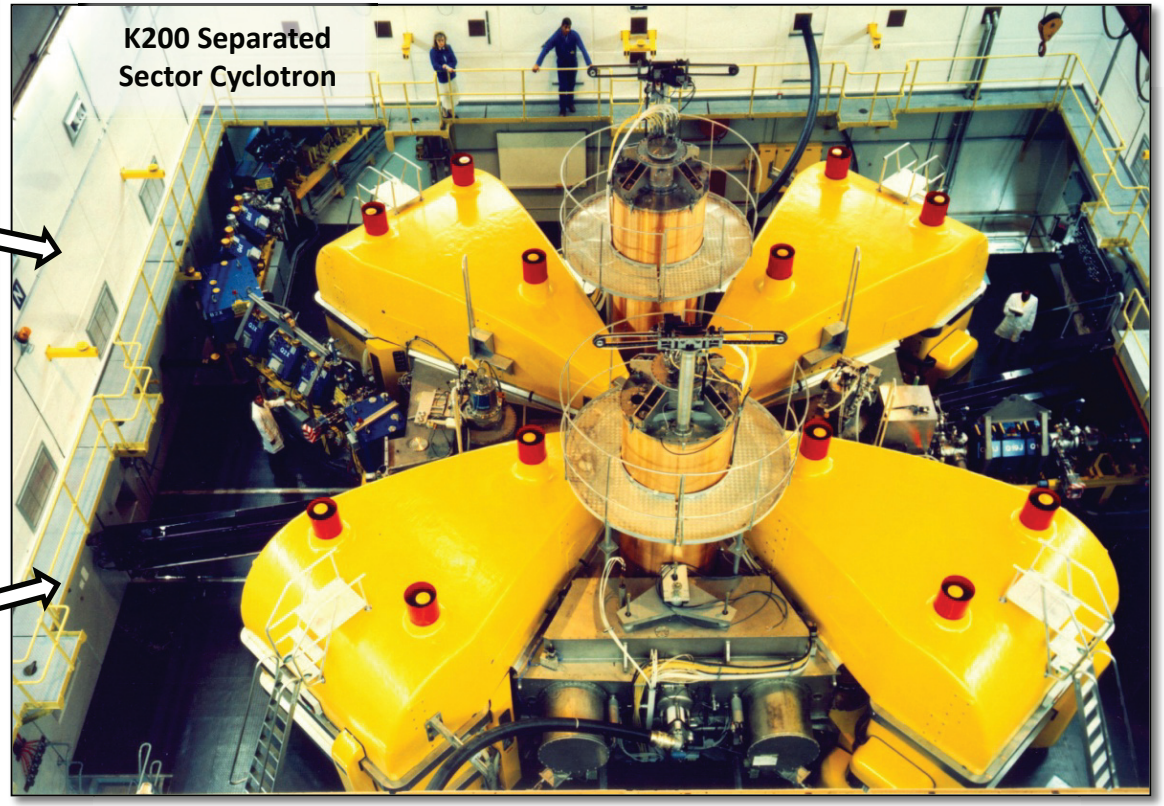
Outline of the Talk

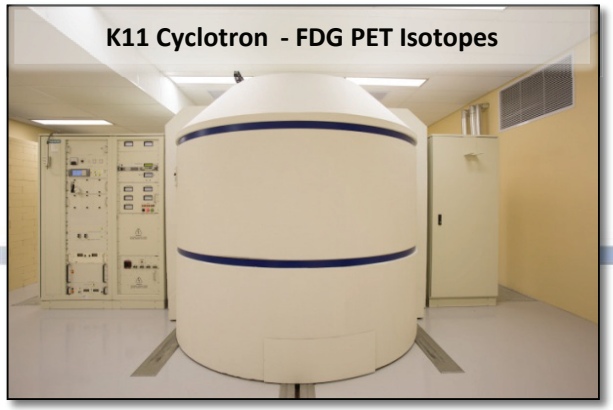
- Current status and upgrade of the accelerator facilities at iThemba LABS
- Proposed new isotope production facilities
- New radioactive ion beam facility

Accelerators at iThemba LABS

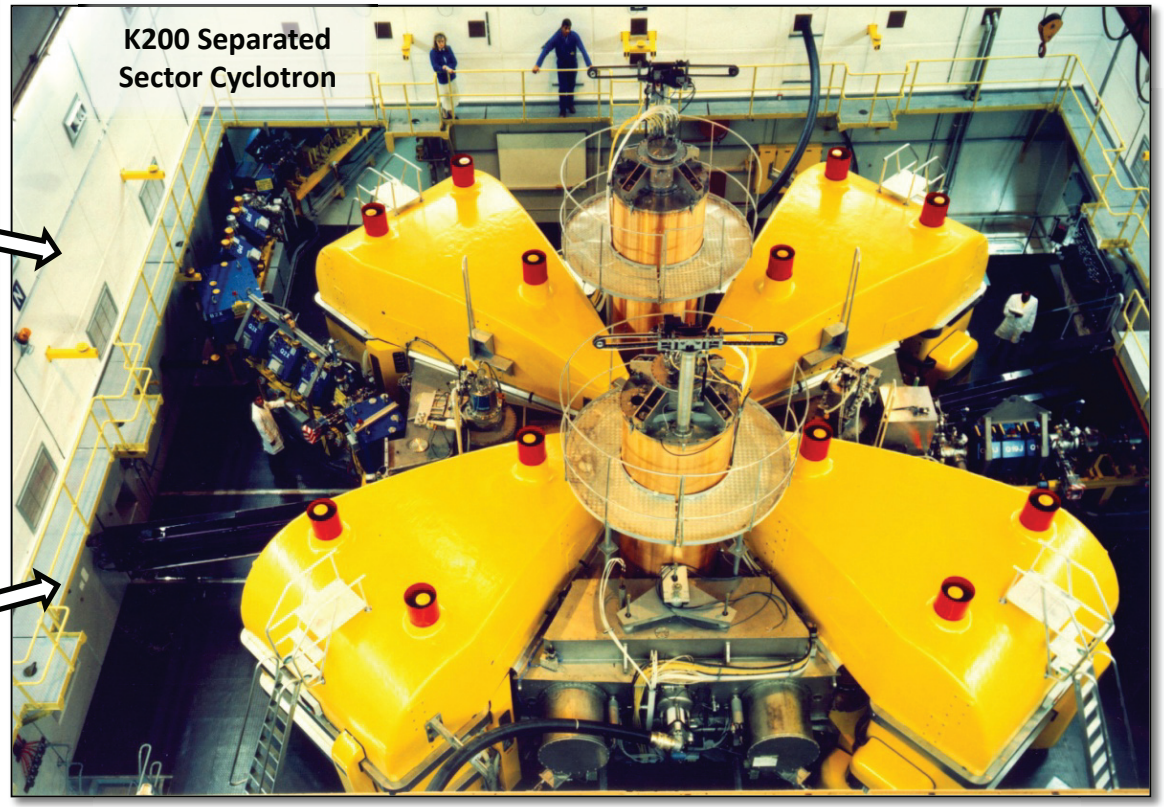


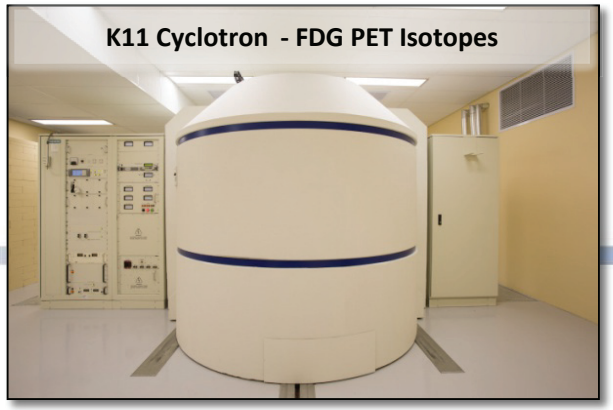
Accelerators at iThemba LABS

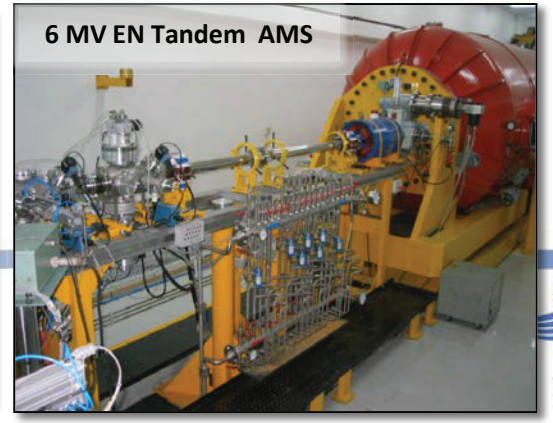




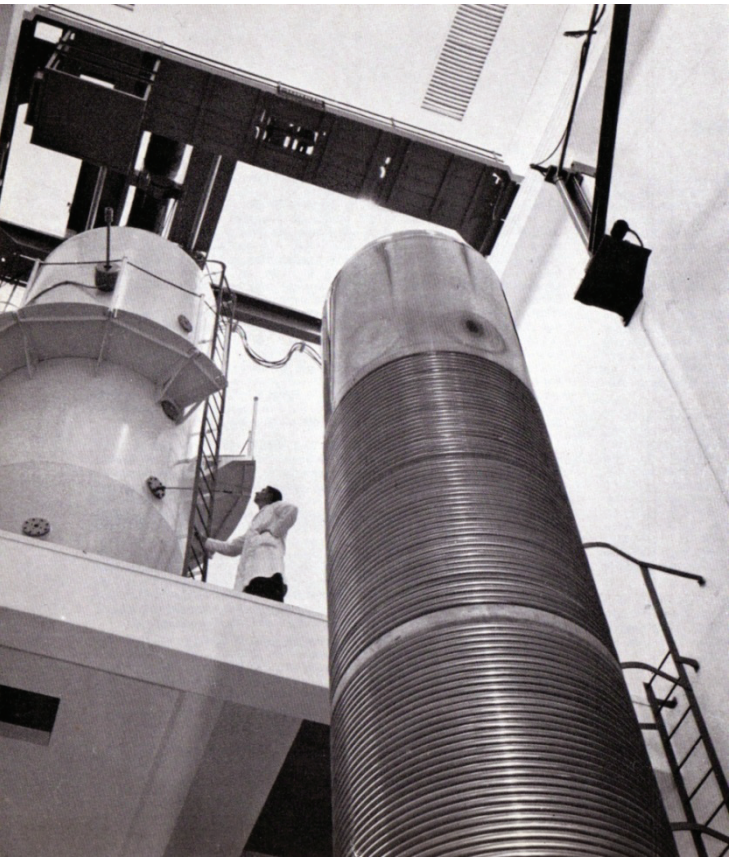
Accelerators at iThemba LABS



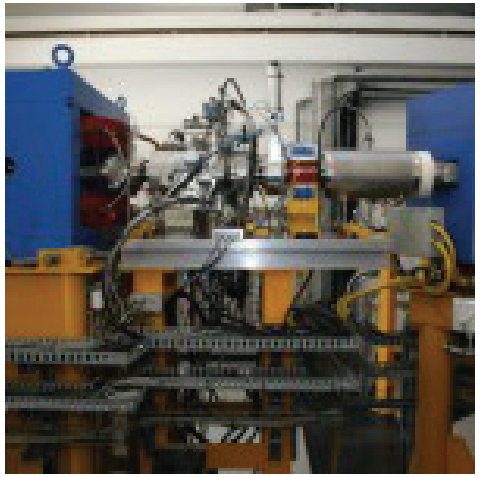


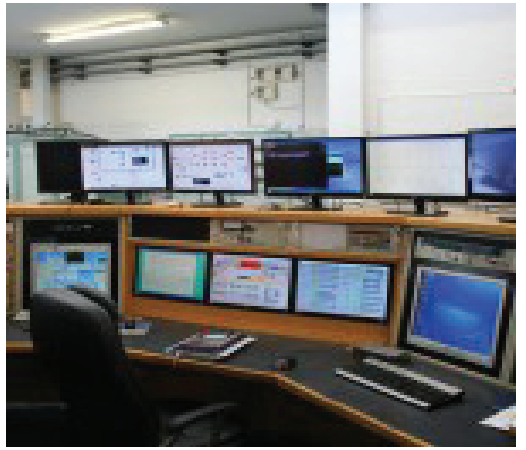


New Tandetron to be installed in first quarter of 2017



AMS Department, based at University of the Witwatersrand





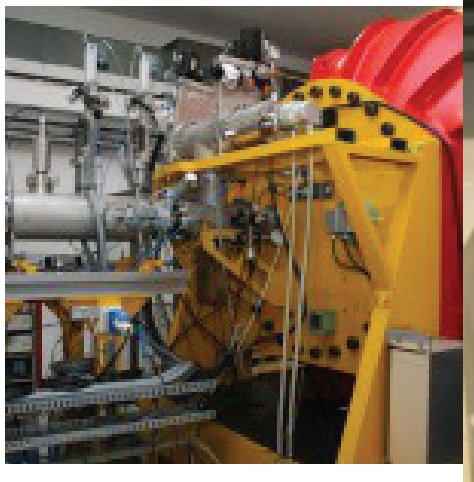
6 MV Tandem (Gauteng): Previously Schonland Research Centre of the University of the Witwatersrand Extensively refurbished and Fitted with a Ion Source for Accelerator Mass Spectrometry

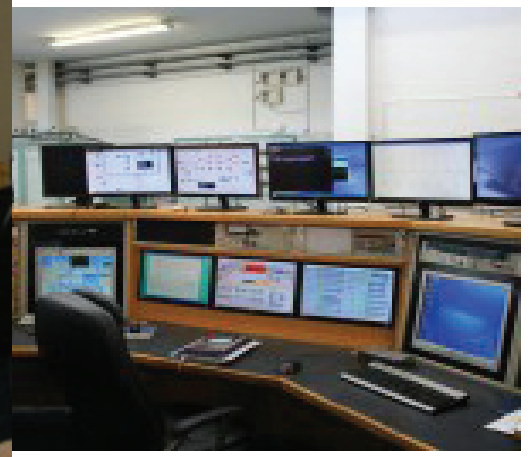
Accelerator Mass Spectrometry (AMS) Facility Unveiled in 2014

science & tech
Department: Science and
REPUBLIC

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

NRF National Research Foundation
iThemba LABS Laboratory for Accelerator Based Sciences





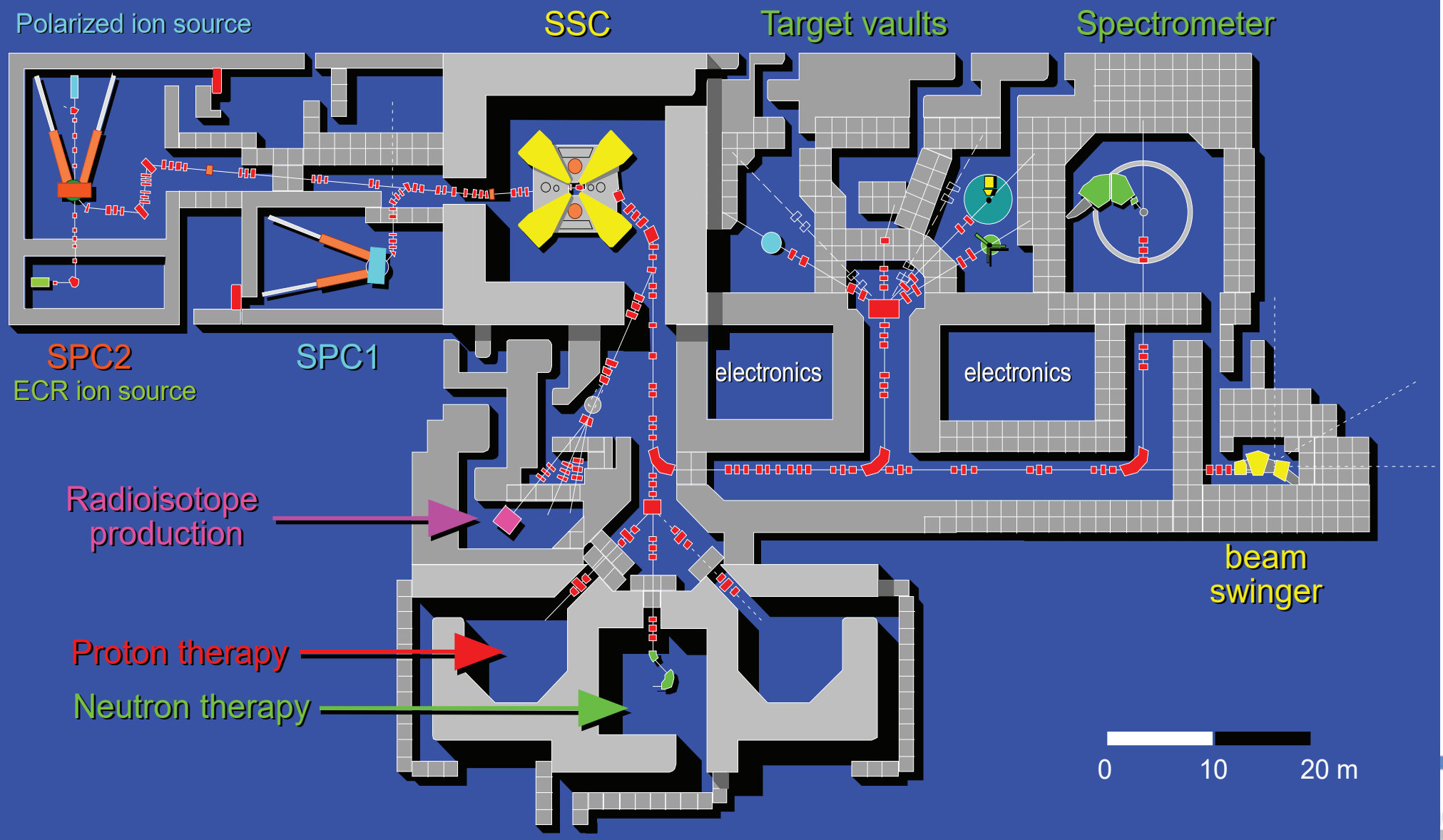
6 MV Tan
Witwaters
Spectrom

iversity of the
ccelerator Mass

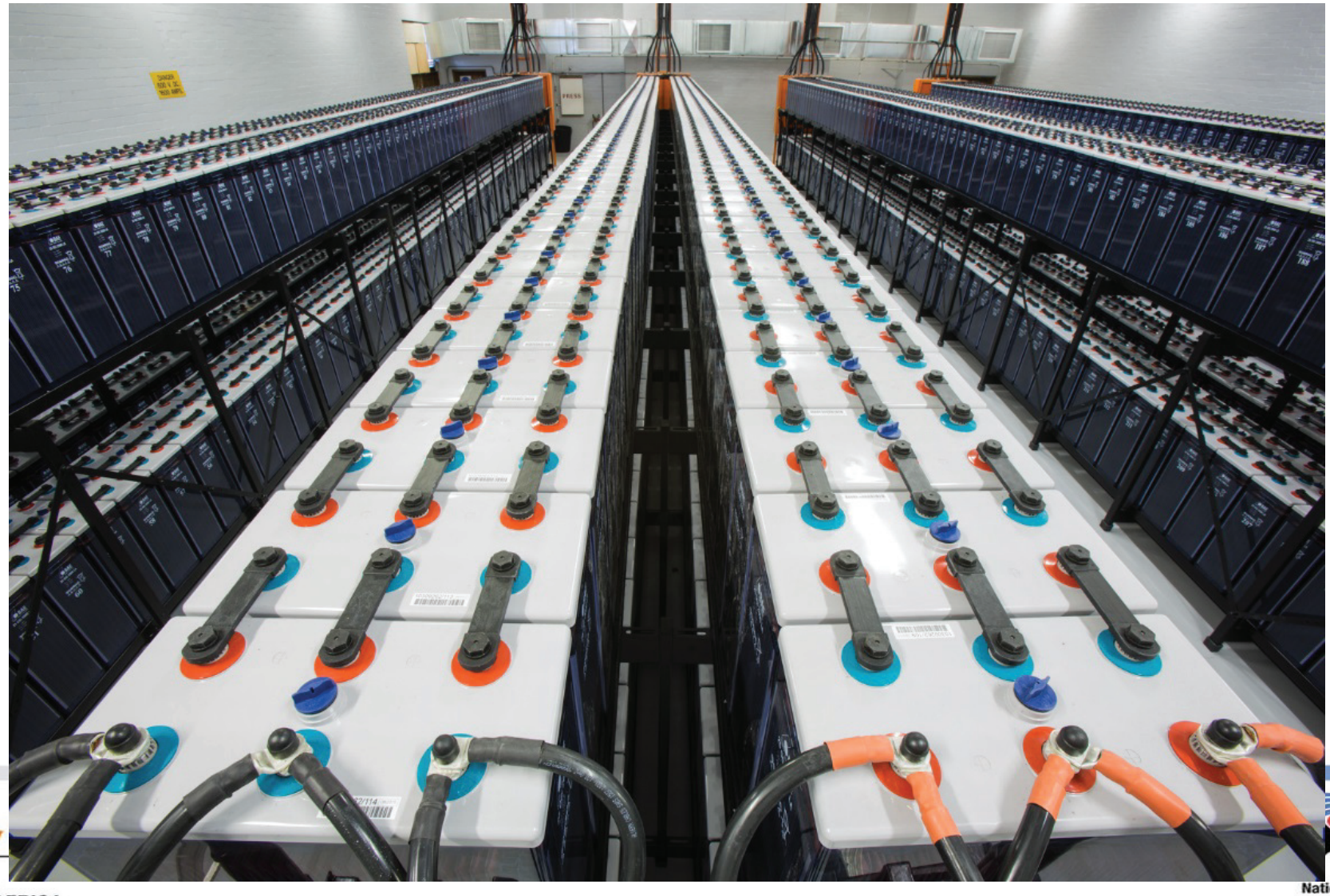
Accelerator Mass Spectrometry (AMS) Facility Unveiled in 2014

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

Separated-Sector Cyclotron Facility



4.4 MVA Uninterruptible Power Supply
New Battery Bank for the UPS



New Cooling Towers 2014

New Chillers and Pumps

Implementation of an EPICS Control System

- Currently 60% of the control hardware is under EPICS control
- Adopted EtherCAT as our new industrial communication standard in 2015
- Put iThemba LABs at a new advantage in that we are able to easily deploy modern off-the-shelf hardware under EPICS control
- Beckhoff EtherCAT terminals
- Real-time industrial solution, available for 25 years
- Fully integrated with EPICS
- 1,000 distributed I/Os in 30 µs

EtherCAT Technology Group

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

Designed for Maintainability

- All system modules are easily removed
- N-Type connectors to RF systems
- All RF signals are easily accessible from the front
- Power supplies are easily accessible from the rear

Complete Solution

iThemba LABS

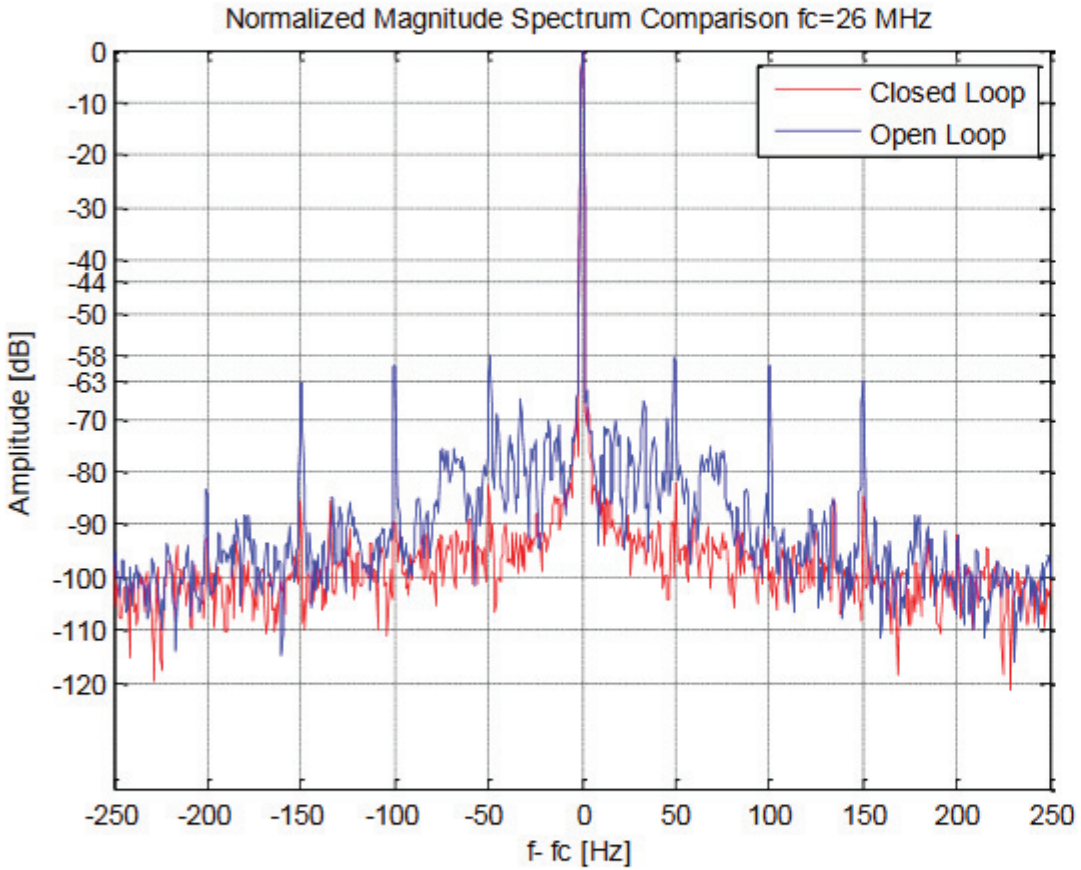
RF Control

&

Beckhoff

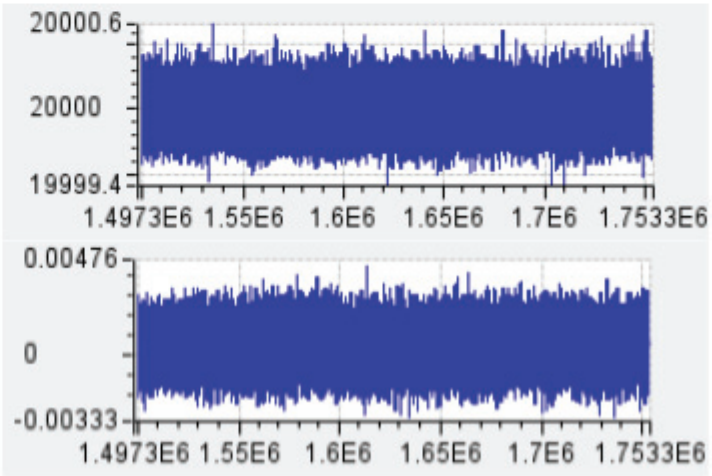
Power amplifier, anode,
grid, trimmer, coupling capacitor
and short circuit plate control

Best Performance



f_c	26 MHz
Power	12 kW
Open-loop SFDR	58 dB
Closed-loop SFDR	> 80 dB
Closed-loop Amplitude Stability	Better than 0.01%
Closed-loop Phase Stability	Better than 0.01 °

Amplitude and Phase Read Back of New System, Fs=2.5kHz

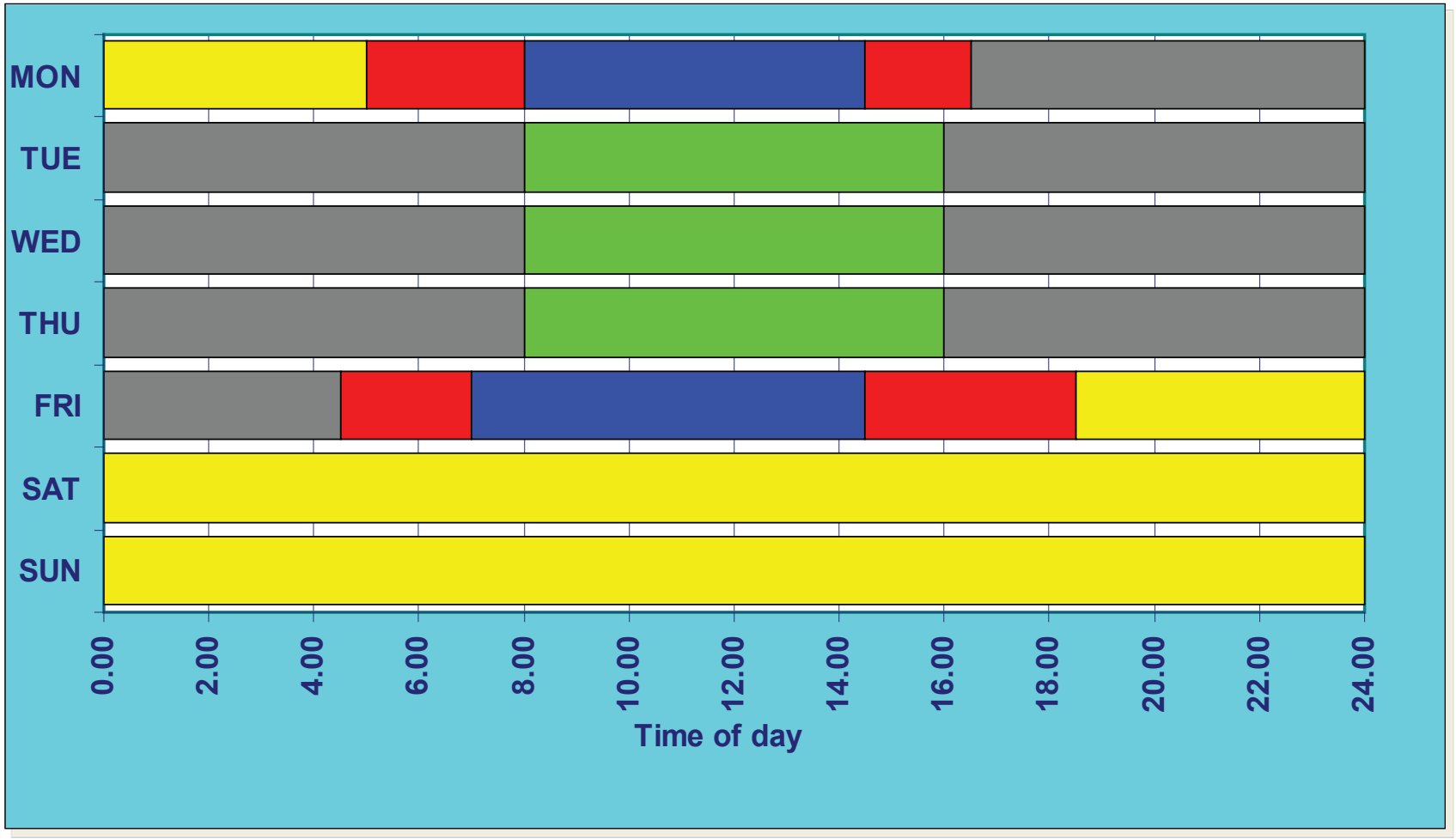


Amplitude Reference
Setpoint: 20000

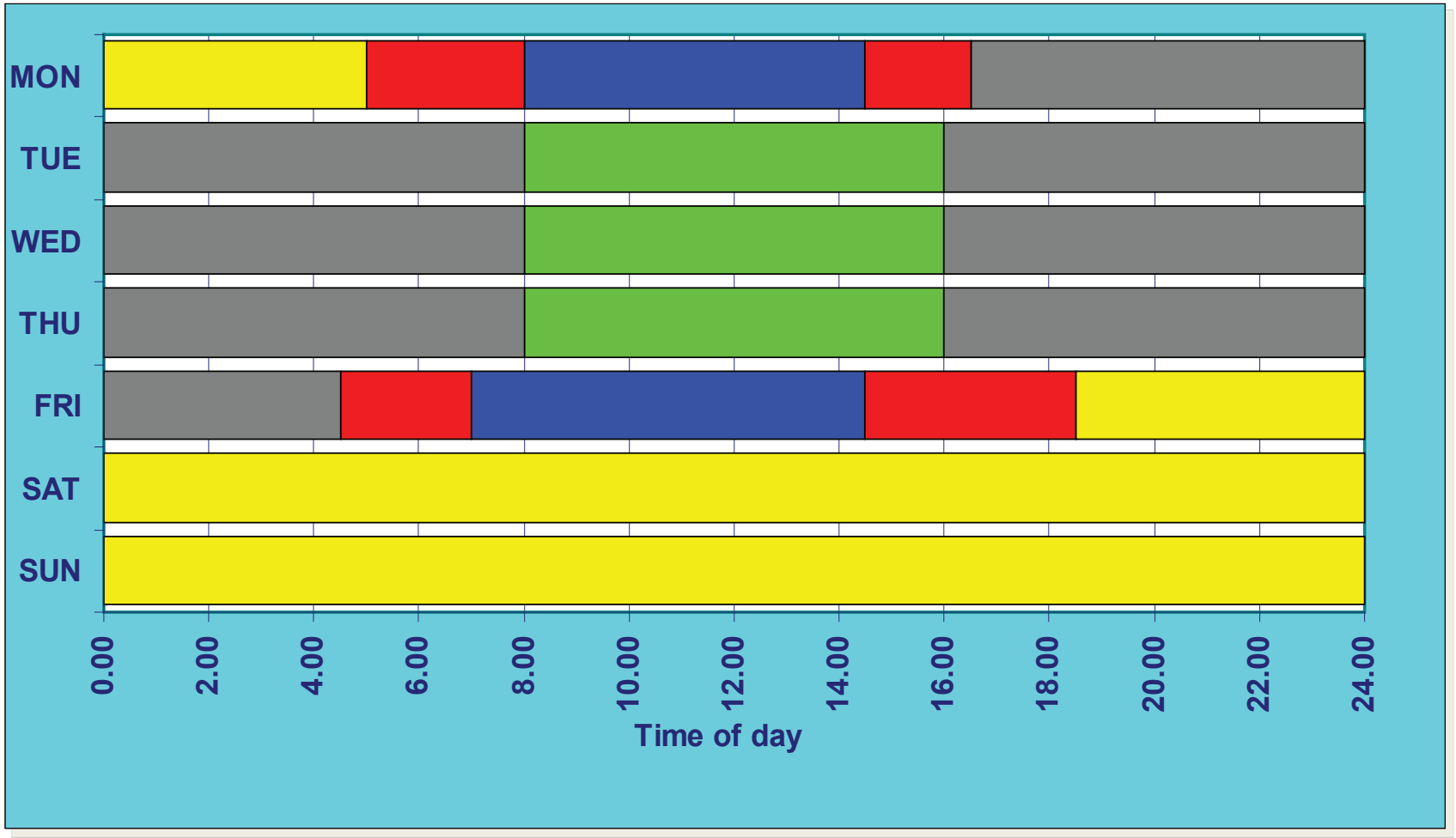
Phase
Setpoint: 0 °

Beam Schedule

Beam Schedule



Beam Schedule



© Nuclear Physics

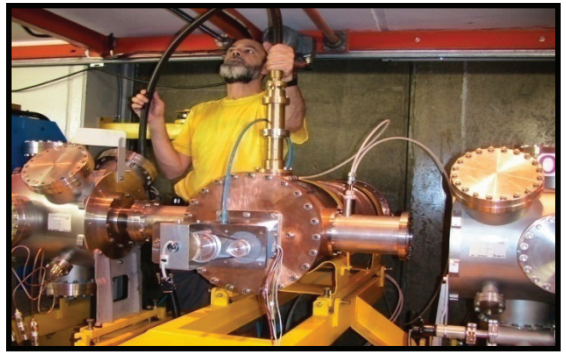
© Neutron Therapy

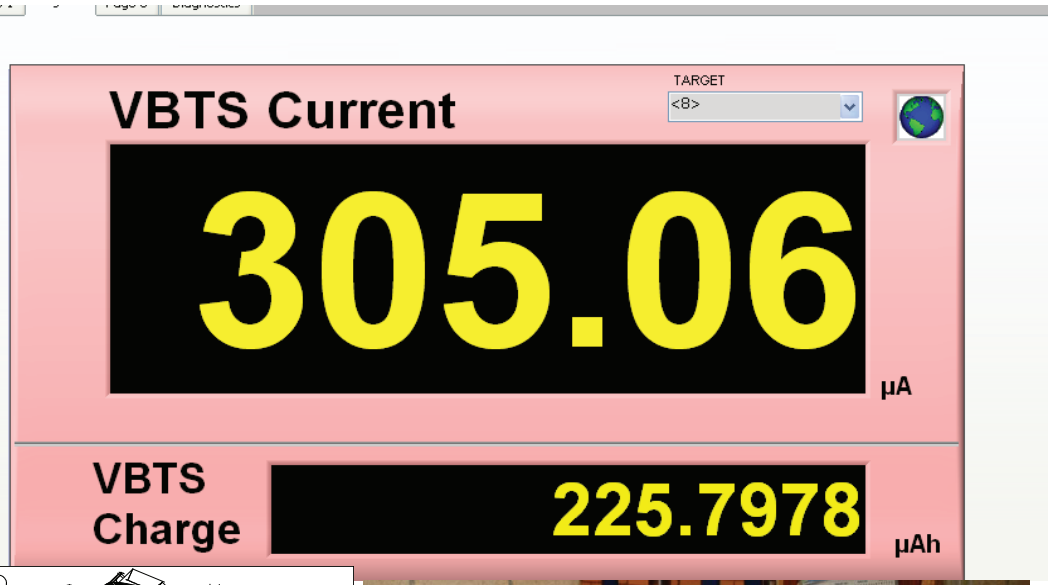
© Proton Therapy

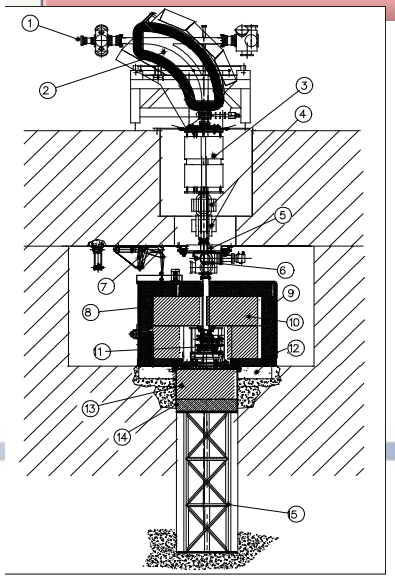
© Energy Change

© Isotope Production

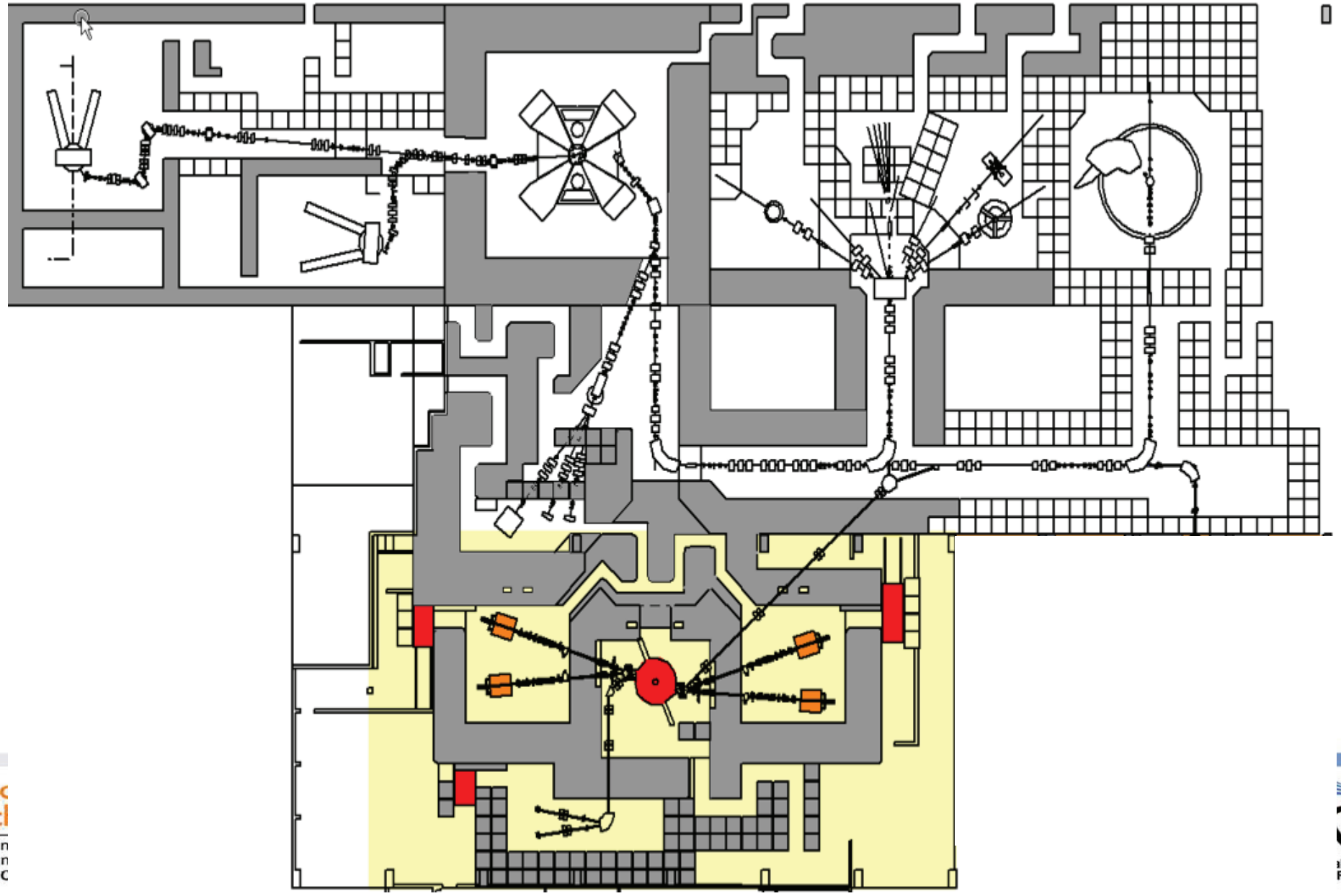
Increase beam intensity (66 MeV protons) for isotope production



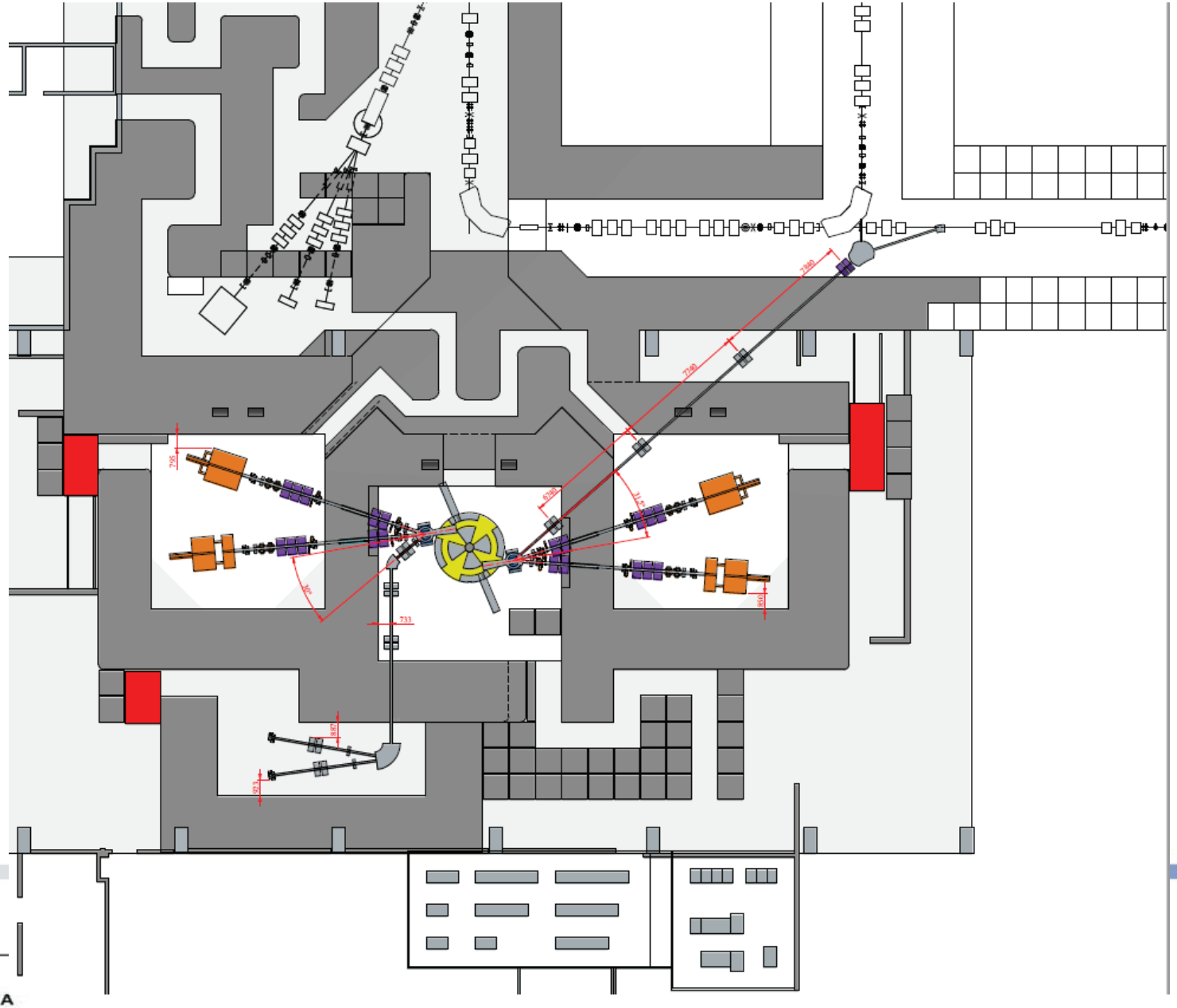




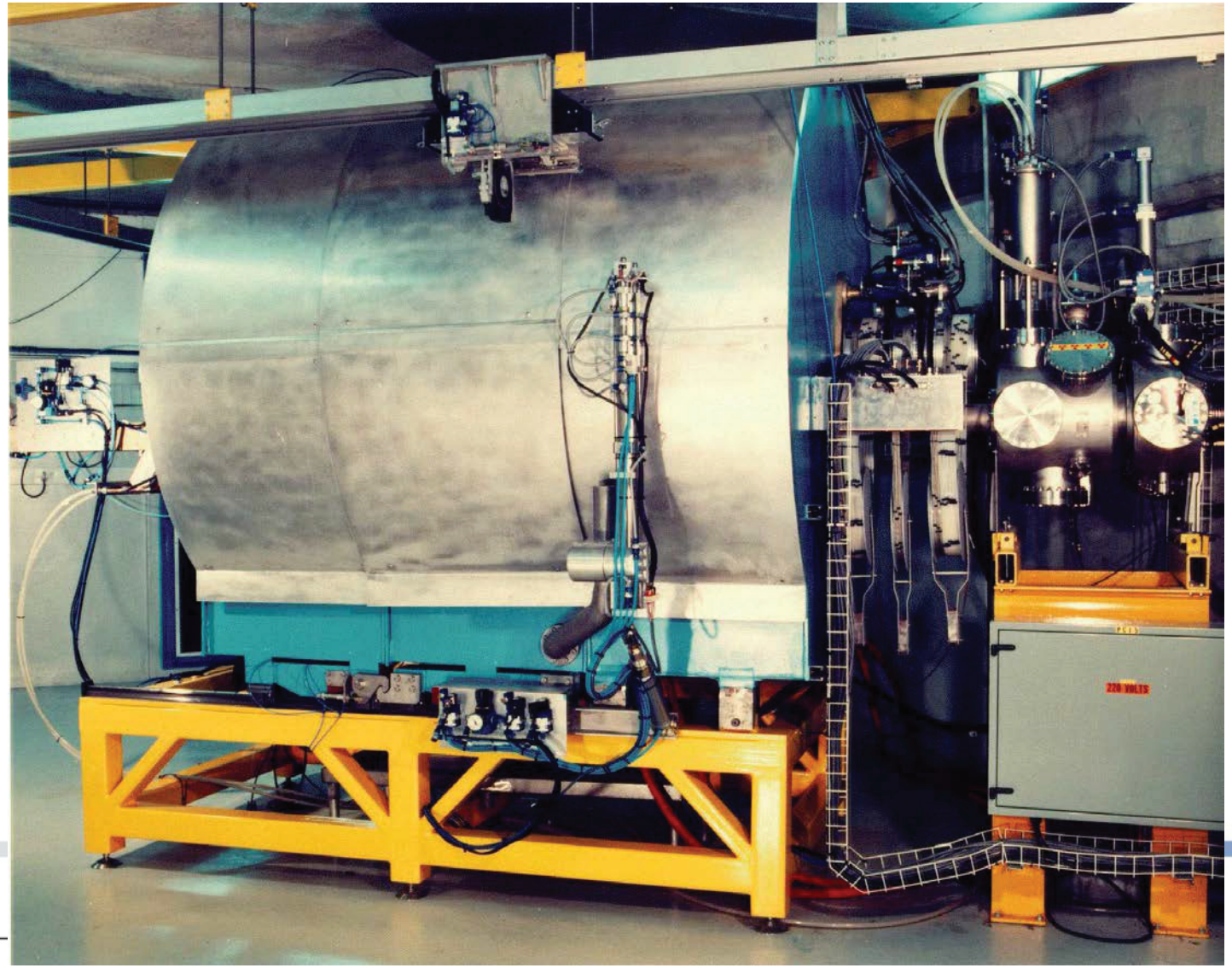
New Facilities at iThemba LABS



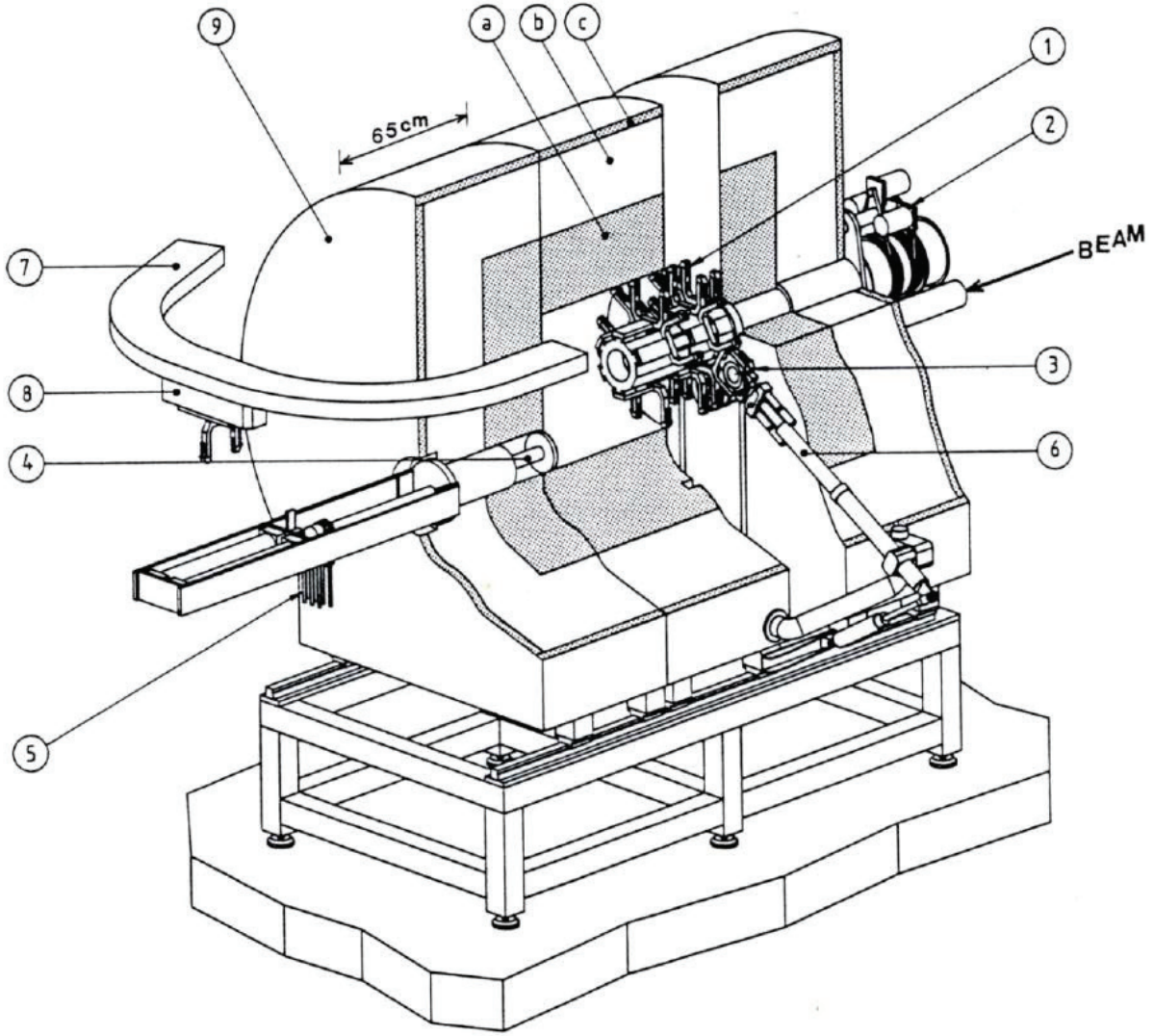
Proposed isotope production facility

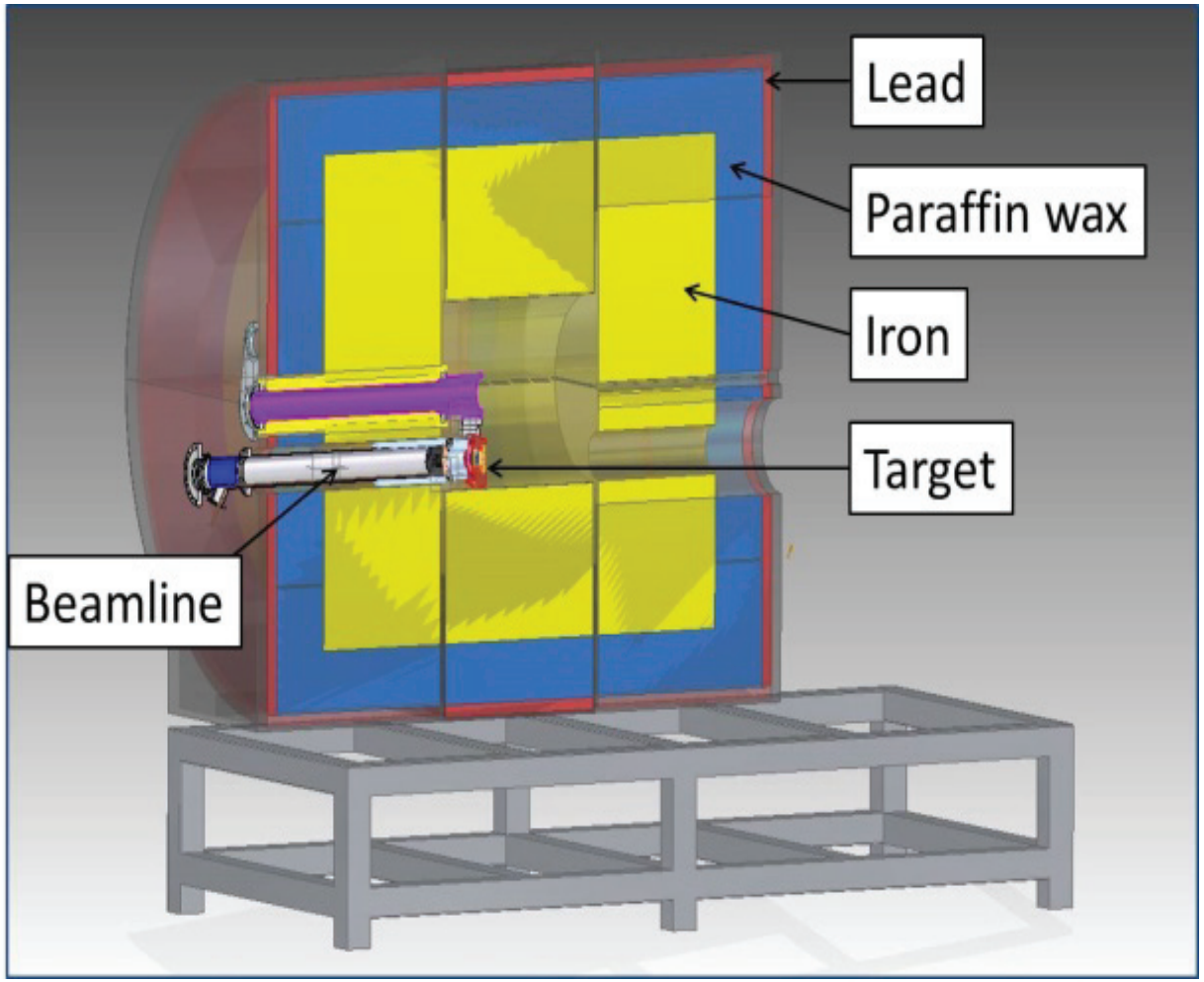


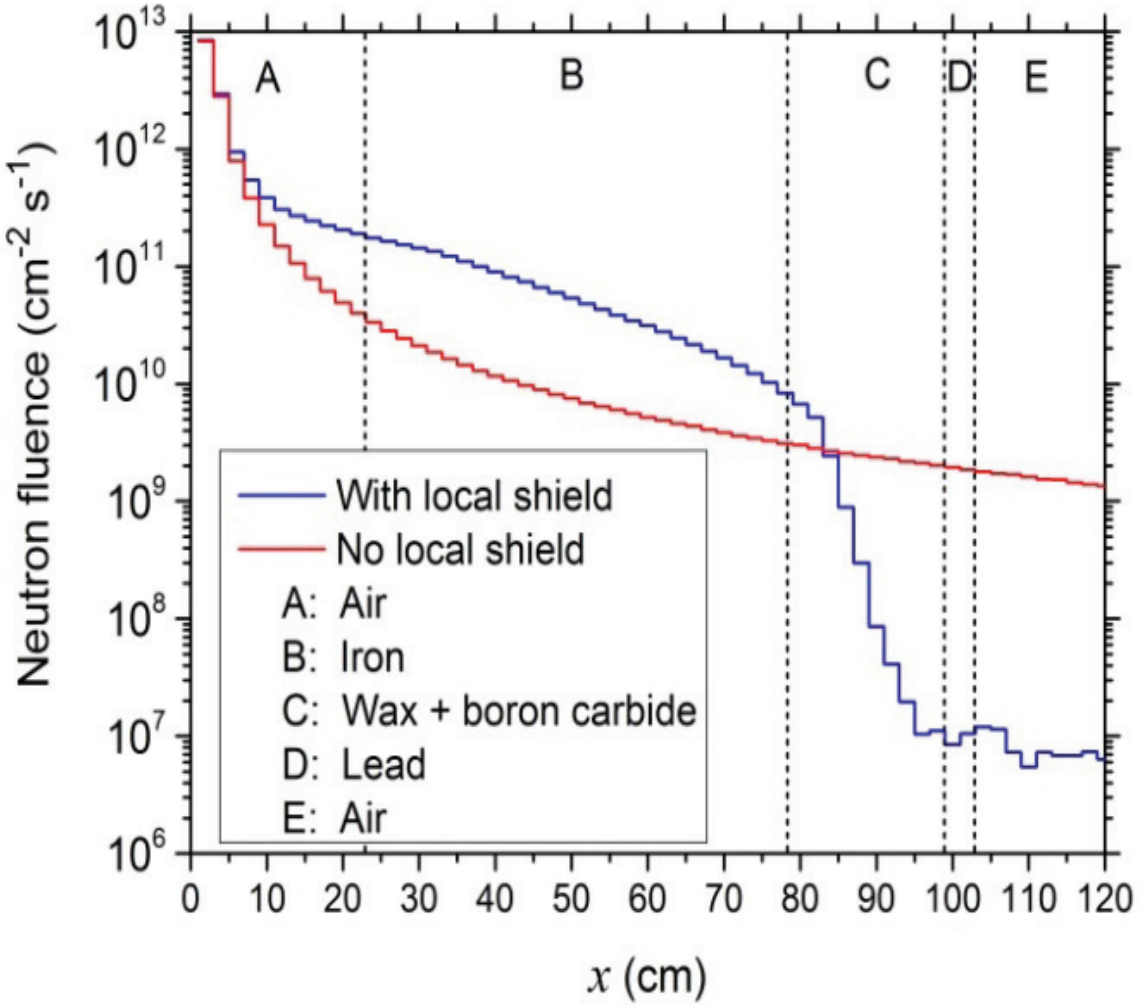
Bombardment station



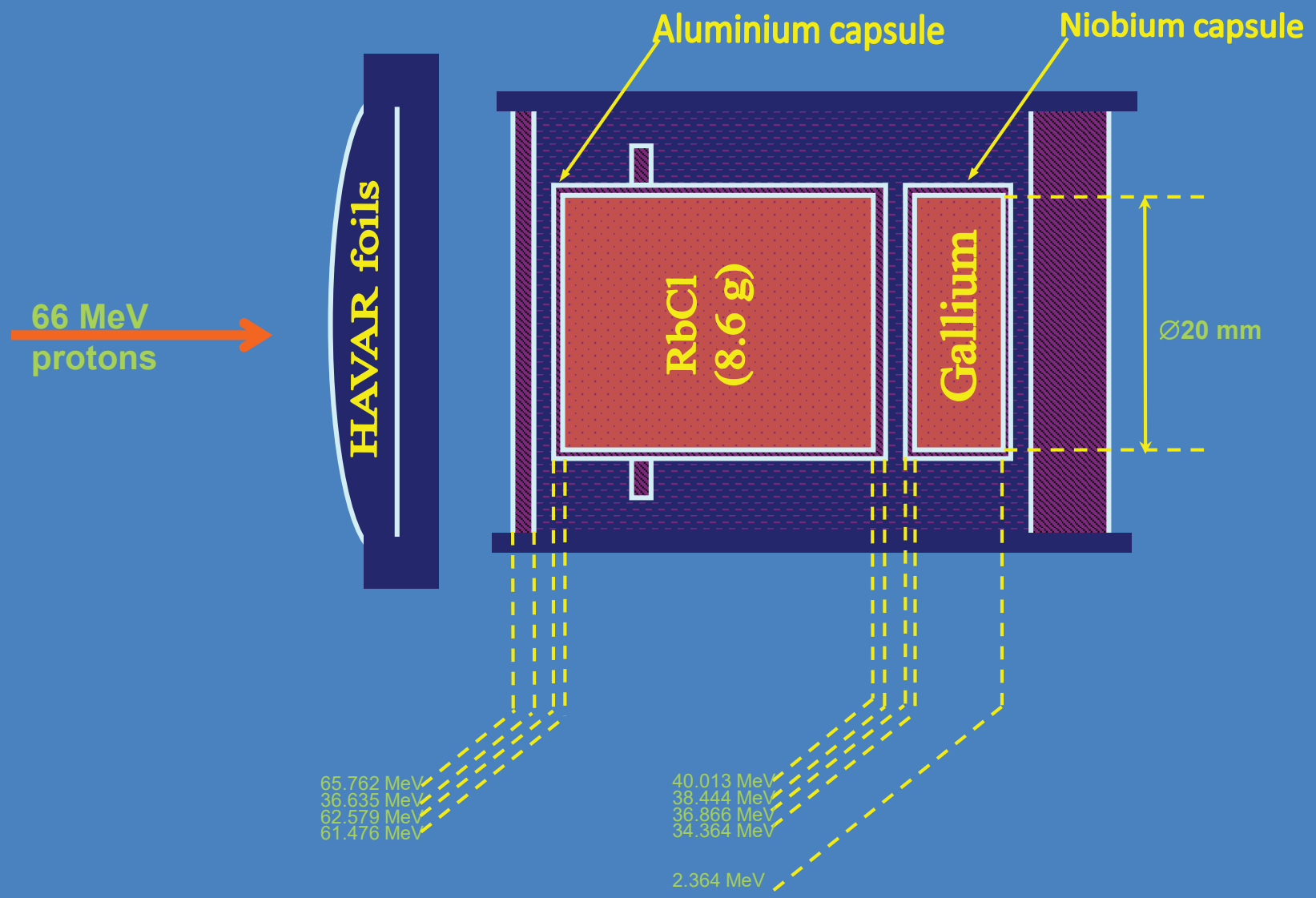
The horizontal-beam target station



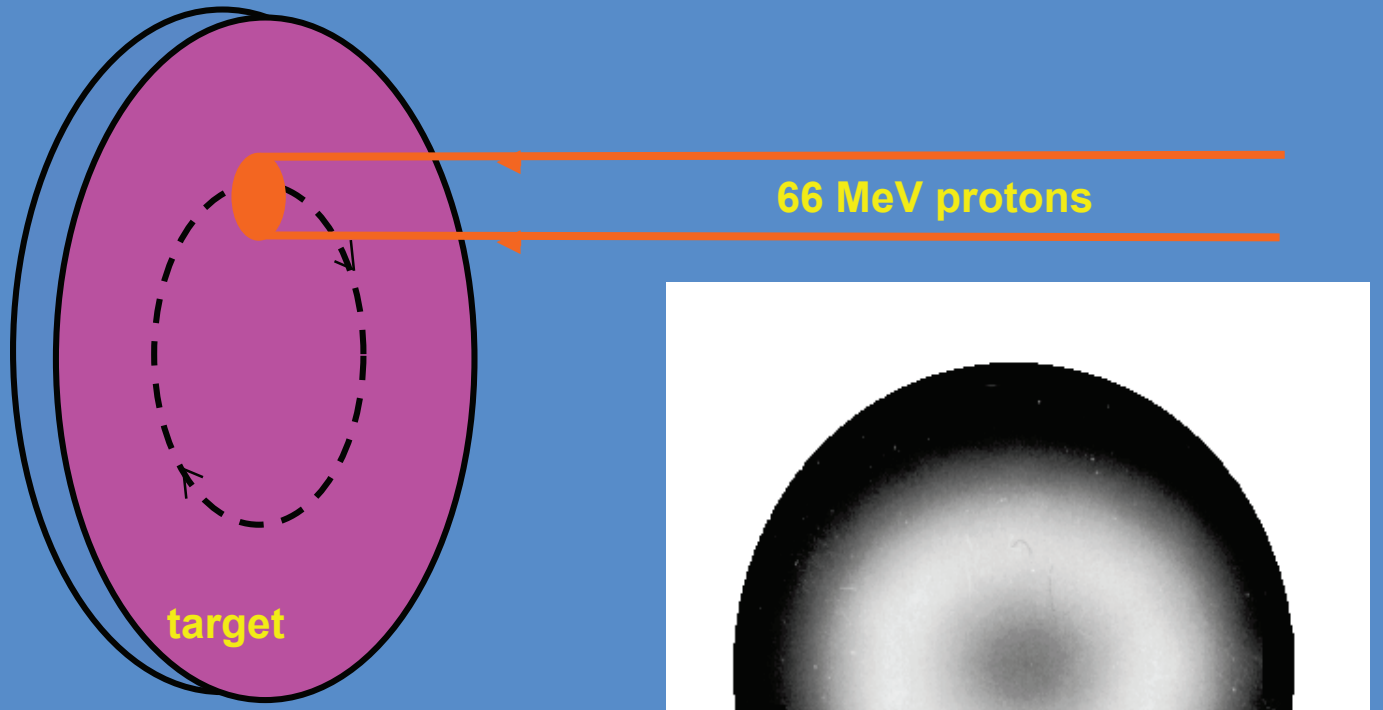

Lead
Paraffin wax
Iron
Target
Beamline

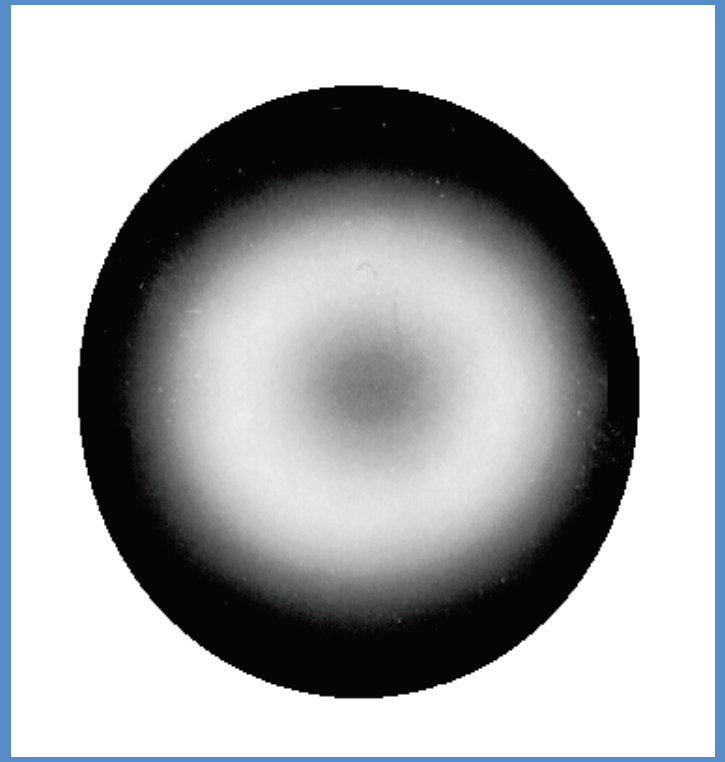

A
B
C
D
E
Neutron fluence (cm^{-2} s^{-1})
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
With local shield
No local shield
A: Air
B: Iron
C: Wax + boron carbide
D: Lead
E: Air
0 10 20 30 40 50 60 70 80 90 100 110 120
x (cm)

Tandem target for the production of ^{82}Sr and ^{68}Ge



Circular beam sweeping





Current Radiopharmaceuticals in routine production

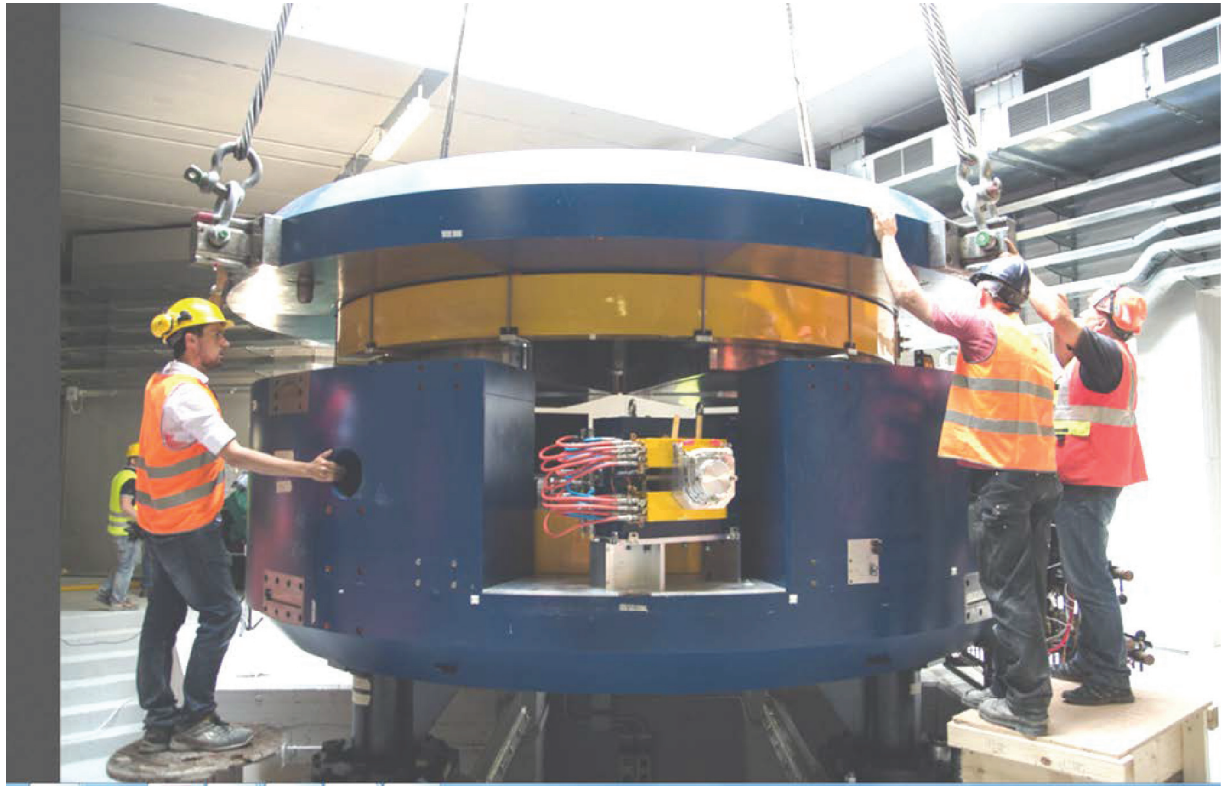
Radionuclide	Half-Life (hours)	Nuclear Reaction	Radiopharmaceutical Product	Main Use
^{18}F	1.83	$^{15}O(p,n)^{18}F$	^{18}F-FDG	Glucose metabolic studies
^{67}Ga	78.3	$Zn(p,xn)^{67}Ga$ $Ge(p,x)^{67}Ga$	^{67}Ga-citrate	Localization of certain tumours and inflammatory regions
$^{81}Rb/^{81m}Kr$	4.58	$Kr(p,xn)^{81}Rb$	$^{81}Rb/^{81m}Kr$ generator	Lung ventilation studies
^{123}I	13.2	$^{127}I(p,5n)^{123}Xe \rightarrow {}^{123}I$	^{123}I-sodium iodide ^{123}I-mIBG	Thyroid studies Localization of certain tumours such as neuroblastoma, pheochromocytoma

Current Radionuclides in routine production list continue

Radionuclide	Half-Life (days/years)	Nuclear Reaction	Product	Main Use
^{82}Sr	25 days	$Rb(p,xn)^{82}Sr$	Produced as a radionuclide	Used to manufacture $^{82}Sr/^{82}Rb$ generators
^{68}Ge	271 days	$Ga(p,xn)^{68}Ge$	Produced as a radionuclide	Used to manufacture $^{68}Ge/^{68}Ga$ generators or used for calibration of gamma camera's or PET CT scanners
^{88}Y	106.6 days	$Sr(p,xn)^{88}Y$	Produced as a radionuclide	Non –medical application
^{109}Cd	453 days	$Ag(p,xn)^{109}Cd$	Produced as a radionuclide	Non-medical application
^{22}Na	2.602 years	$Mg(p,n)^{22}Na$	Produced as a radionuclide	Positron Annihilation Studies

Company: IBA CYCLOTRON 70

Company: Best Cyclotron Systems BEST 70p Cyclotron



IBA Cyclotron C70

Isochron cyclotron with 4 sectors

RF: 30.45 MHz

Acceleration Voltage: 65 kV

Max magnetic field : 1.6 T

Max kinetic energy/n: 30 - 70 MeV

Total beam current 700 micro A proton beam

BEST 70p Cyclotron - specifications

Beam Current

700 µA, combined beam current

Beam Energy

35 to 70 MeV variable energy extraction

Magnet

Magnet coil ..... ~127 kAT
Magnet weight ..... ~195 tons
Maximum magnetic field ..... 1.6 T
Geometry ..... 4 Sector, deep valley
Hill sector angle ..... 50°
Hill gap ..... 6 to 4.69 cm

RF System

Number of Dees 2
Dee Voltage ..... 60 to 81 kV
RF frequency ..... 58 MHz, 4th harmonic
Power required ..... 28 kW (nominal)

Vacuum System

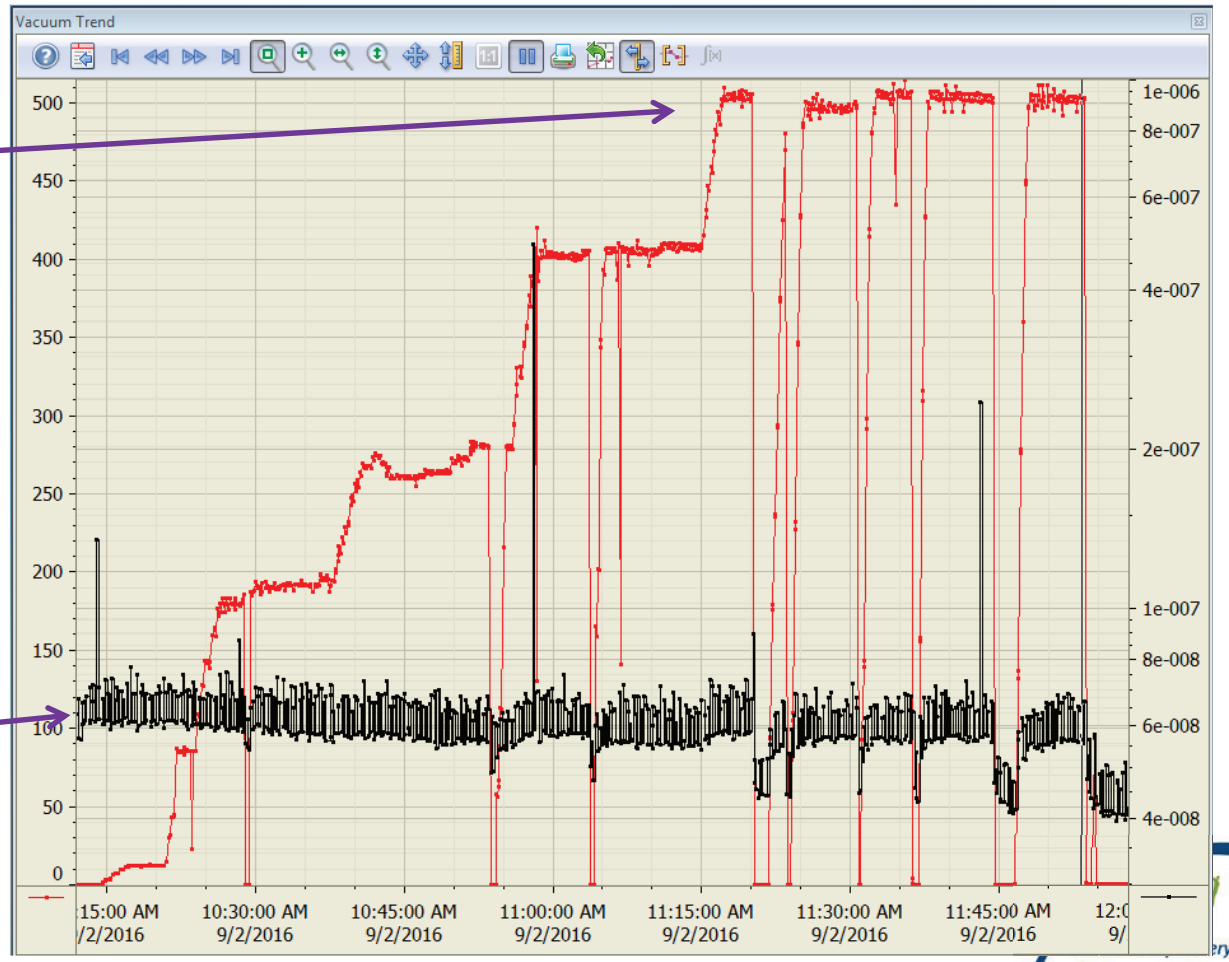
Ion source ..... <1 x 10-5 Torr
Main tank ..... <1.5 x 10-7 Torr
Pumps ..... 7 cryogenic pumps

Beam test on 50kW INFN target

Vacuum:

500μA

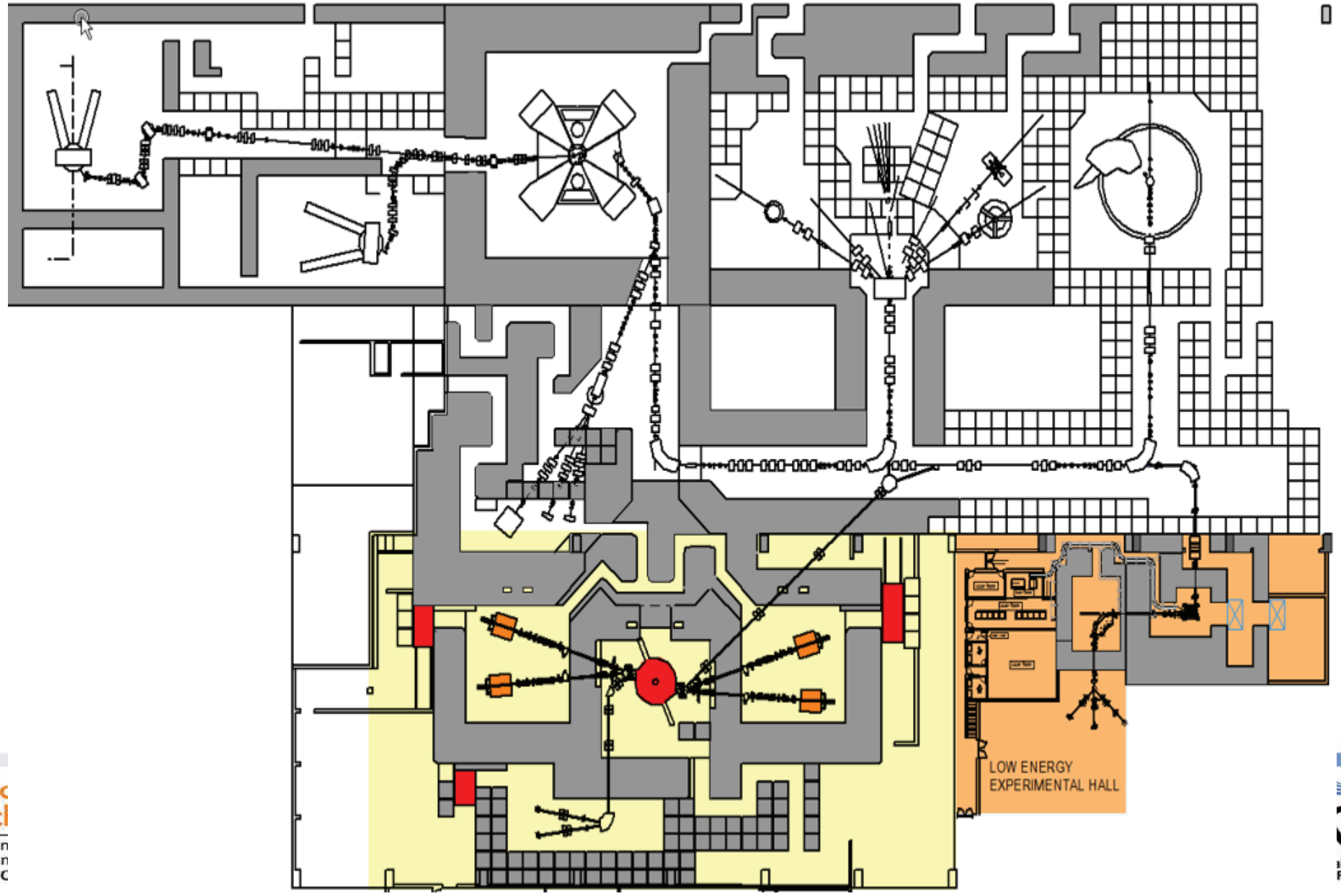
6x10^{-8} Torr



Best Cyclotron Systems, Inc.

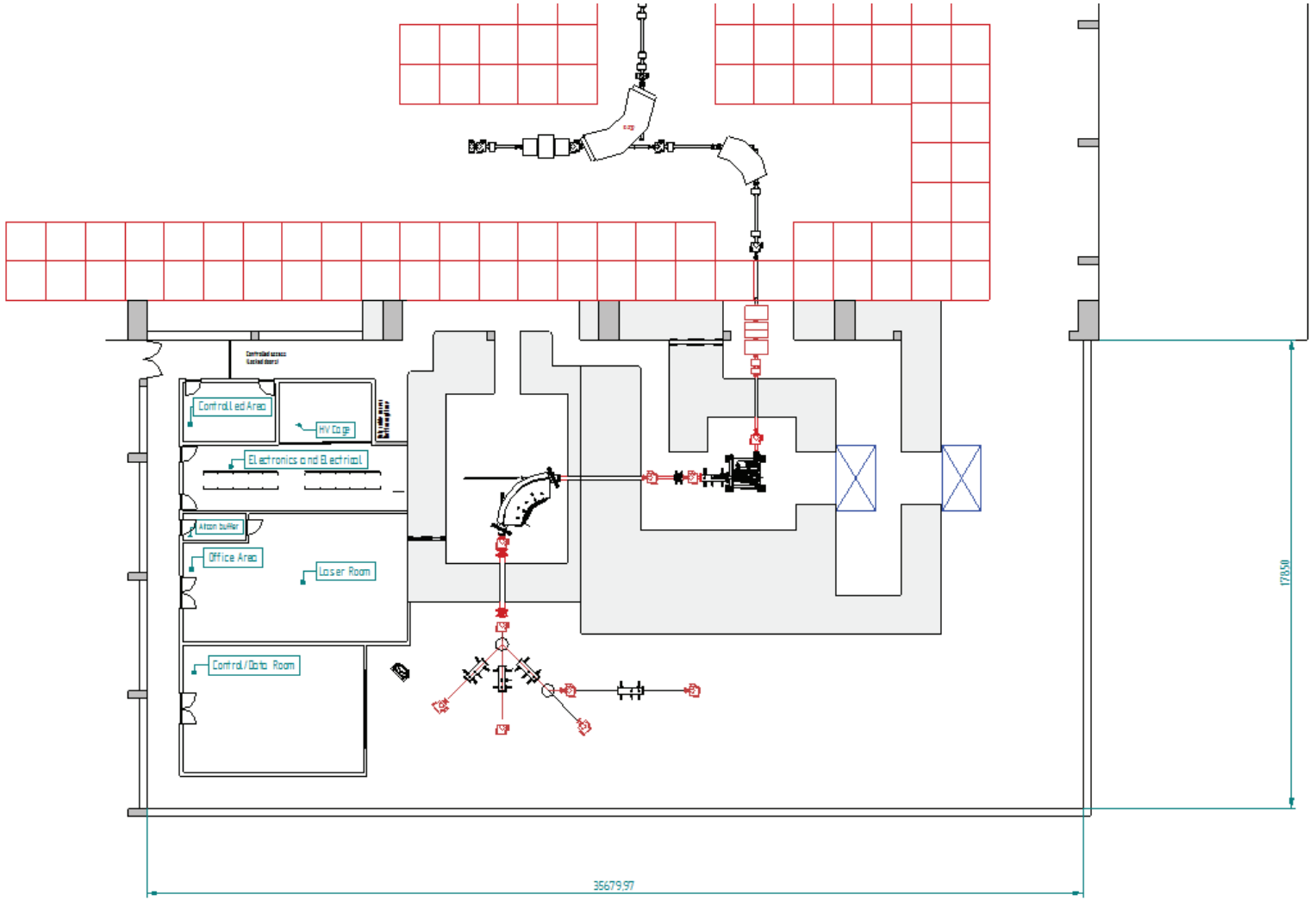
TeamBest Your True Partner

Low Energy Rare Isotope Beam Facilities at iThemba LABS

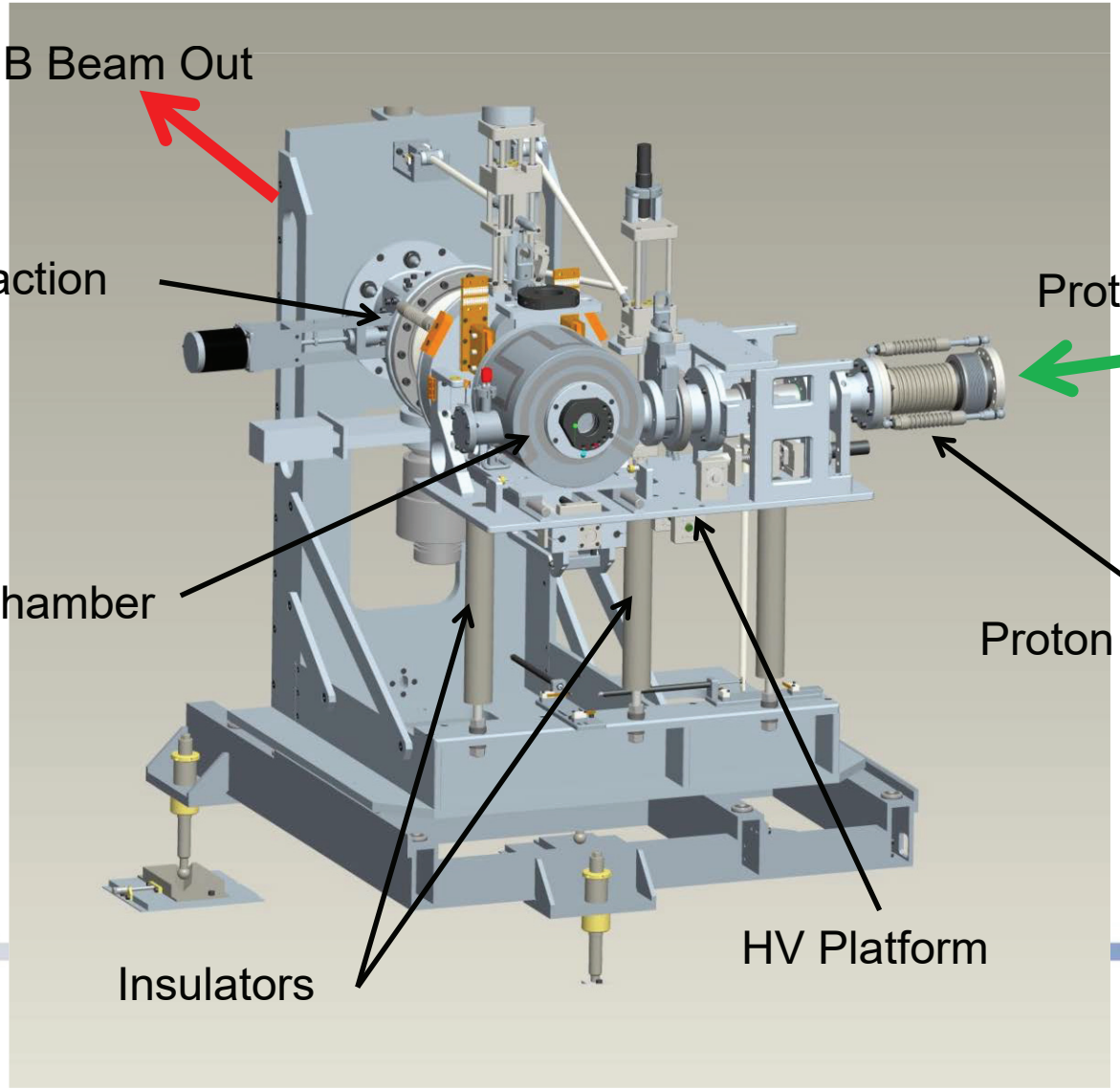


Low Energy Rare Isotope Beamline (LERIB)

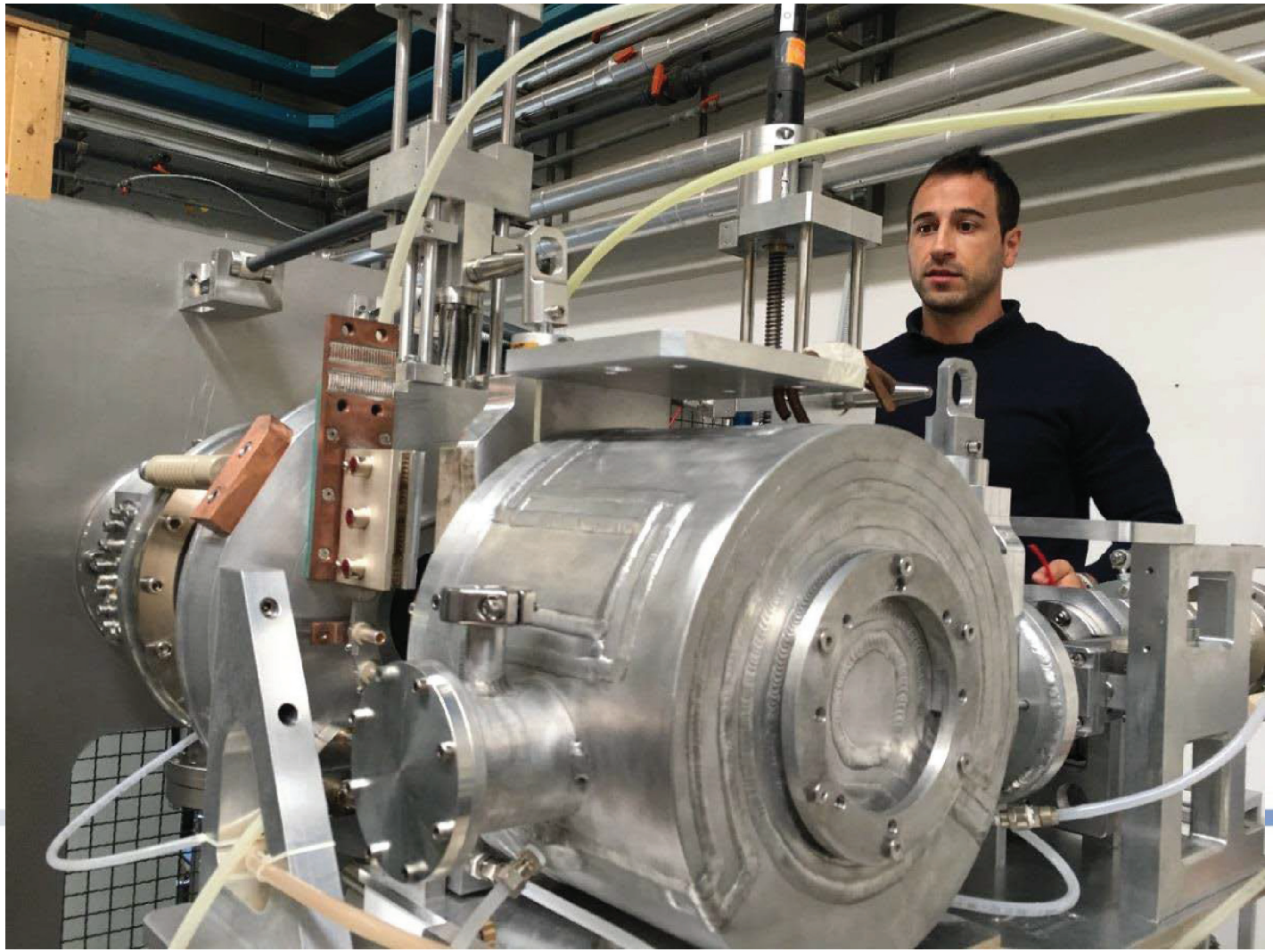
Projects List



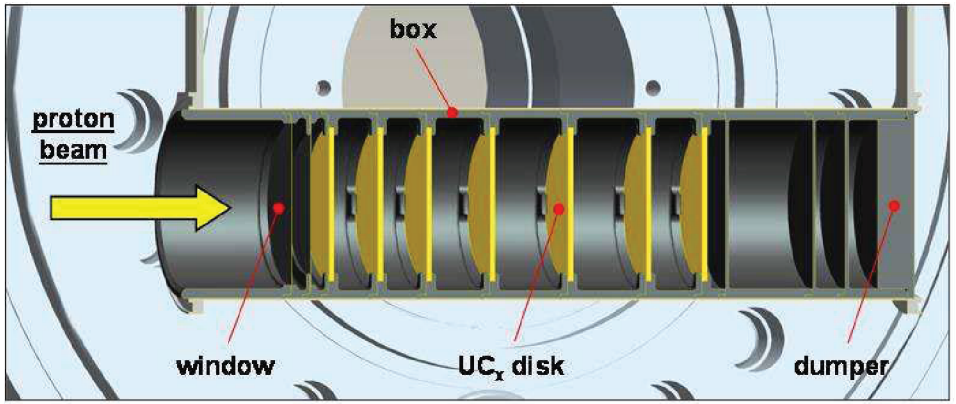
RIB Target Ion Source for SPES project at LNL Legnaro Italy



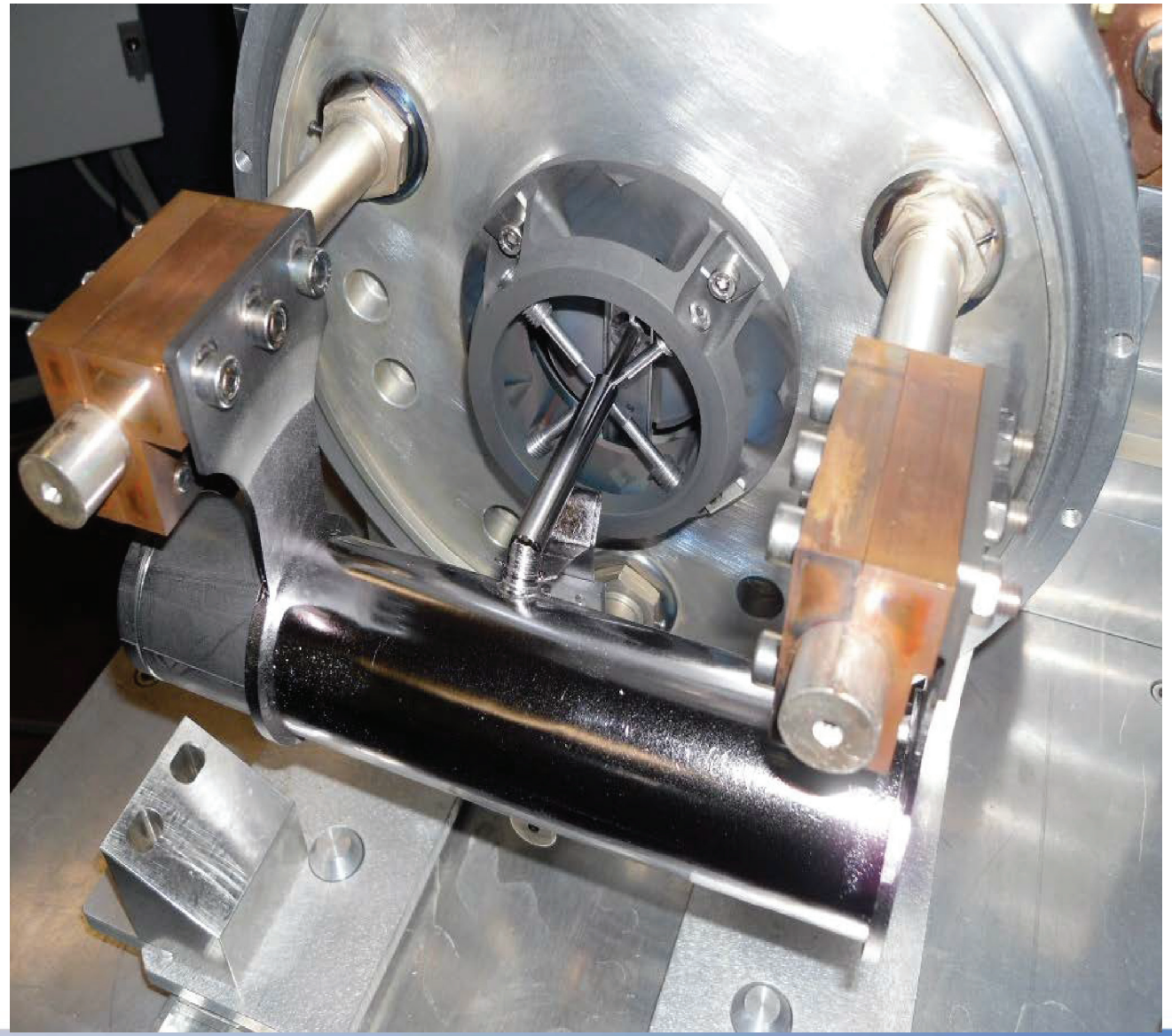
Ion Source for iThemba LABS design and build by LNL, Italy



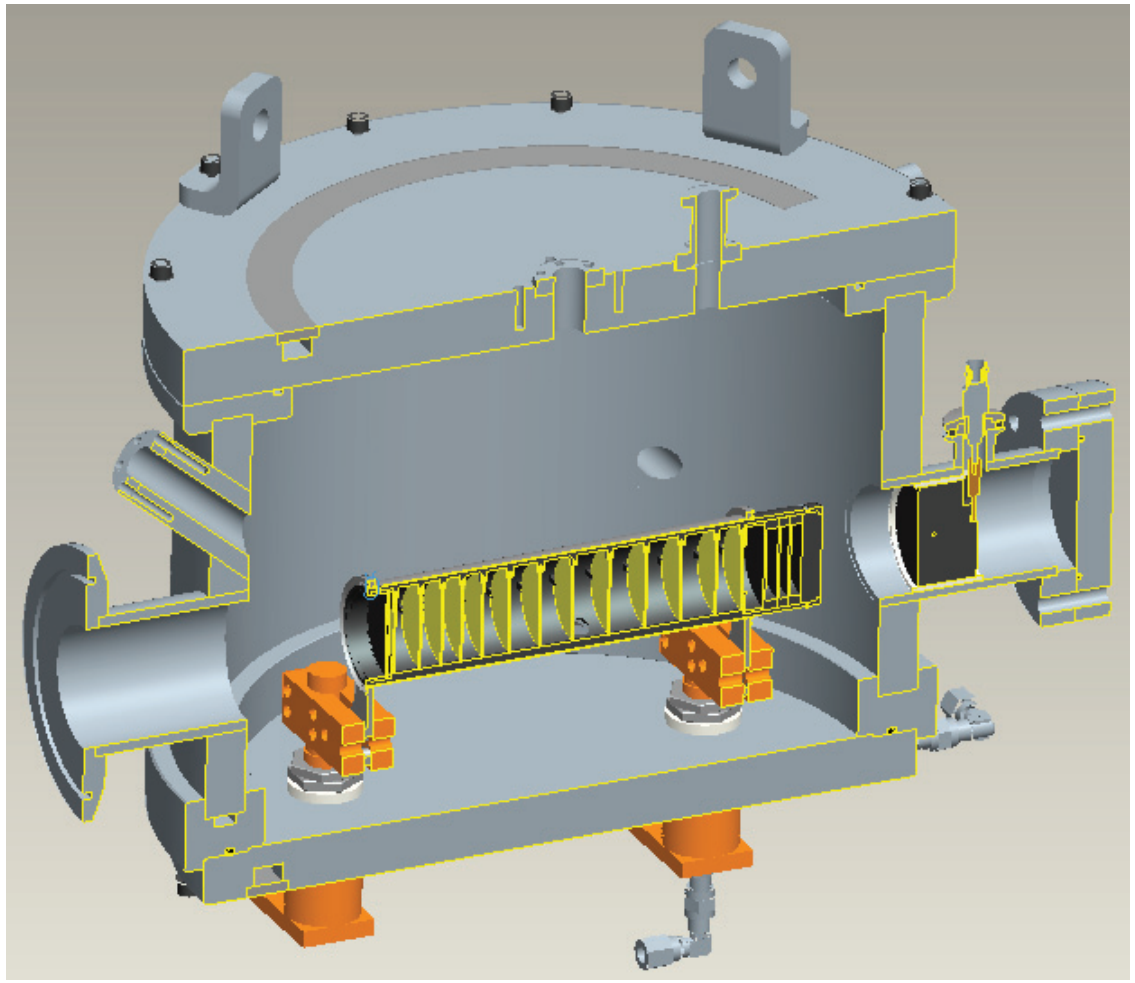
The SPES target (chamber lid removed), designed for a 40 MeV proton beam entering from the right. The heating current flows through the Ta tube, between the copper clamping bars at each end. The small central tube connects the target chamber to the ion source. [Andrighetto 2011]

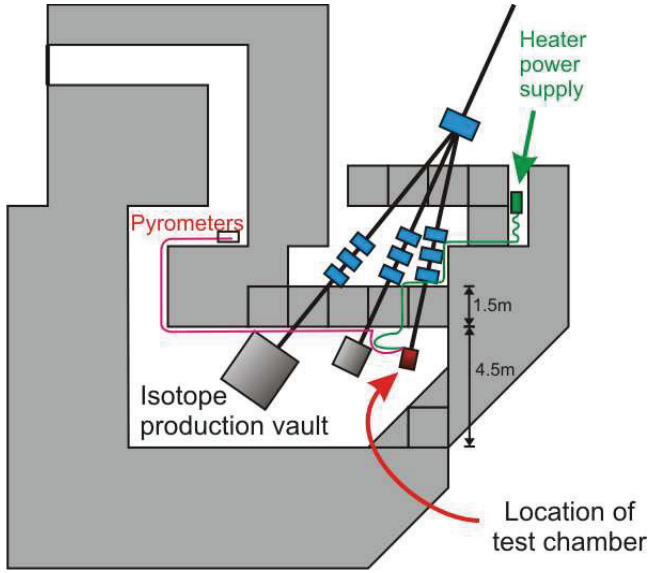


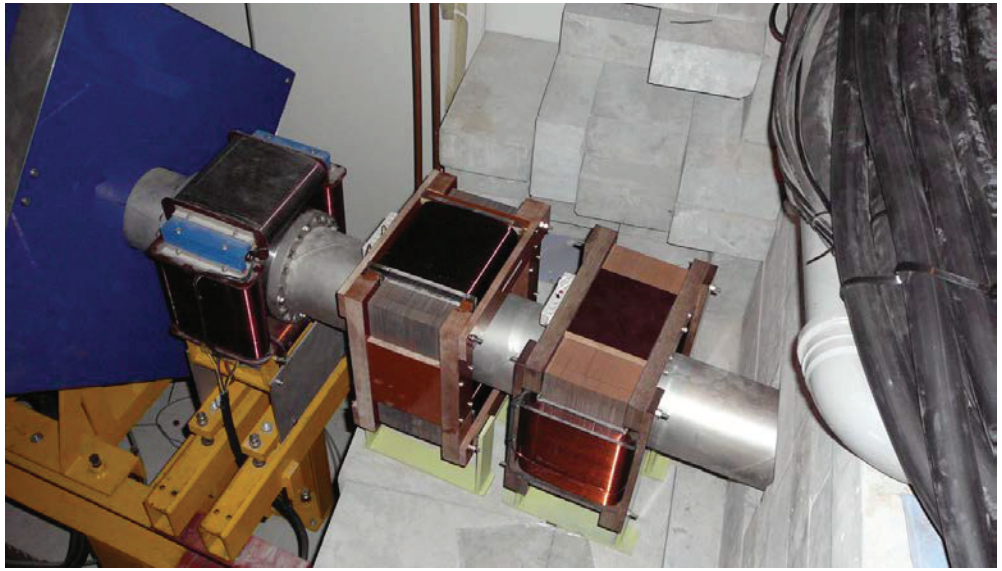
CAD drawing of the SPES target assembly, showing the UC_x disks (yellow) in a graphite tube and also the beam dump disks (dark grey). [SPES 2010]

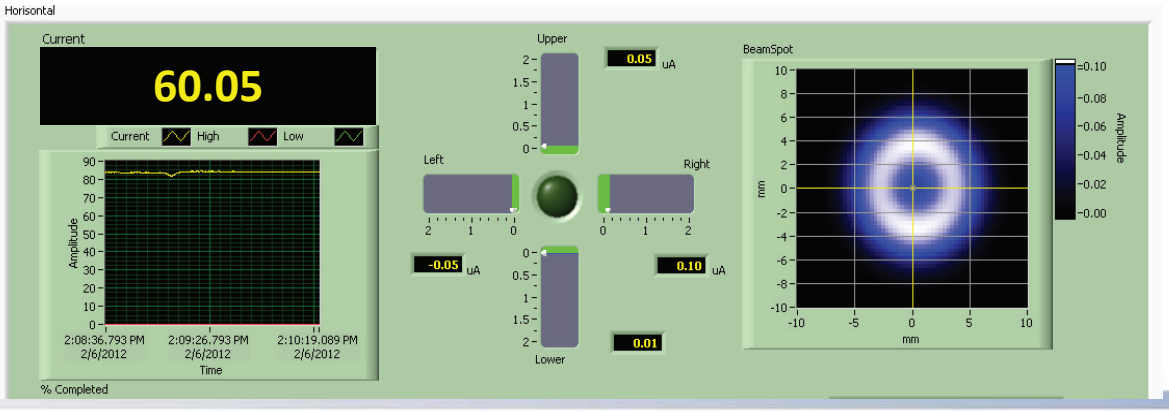


Test Chamber at iThemba LABS

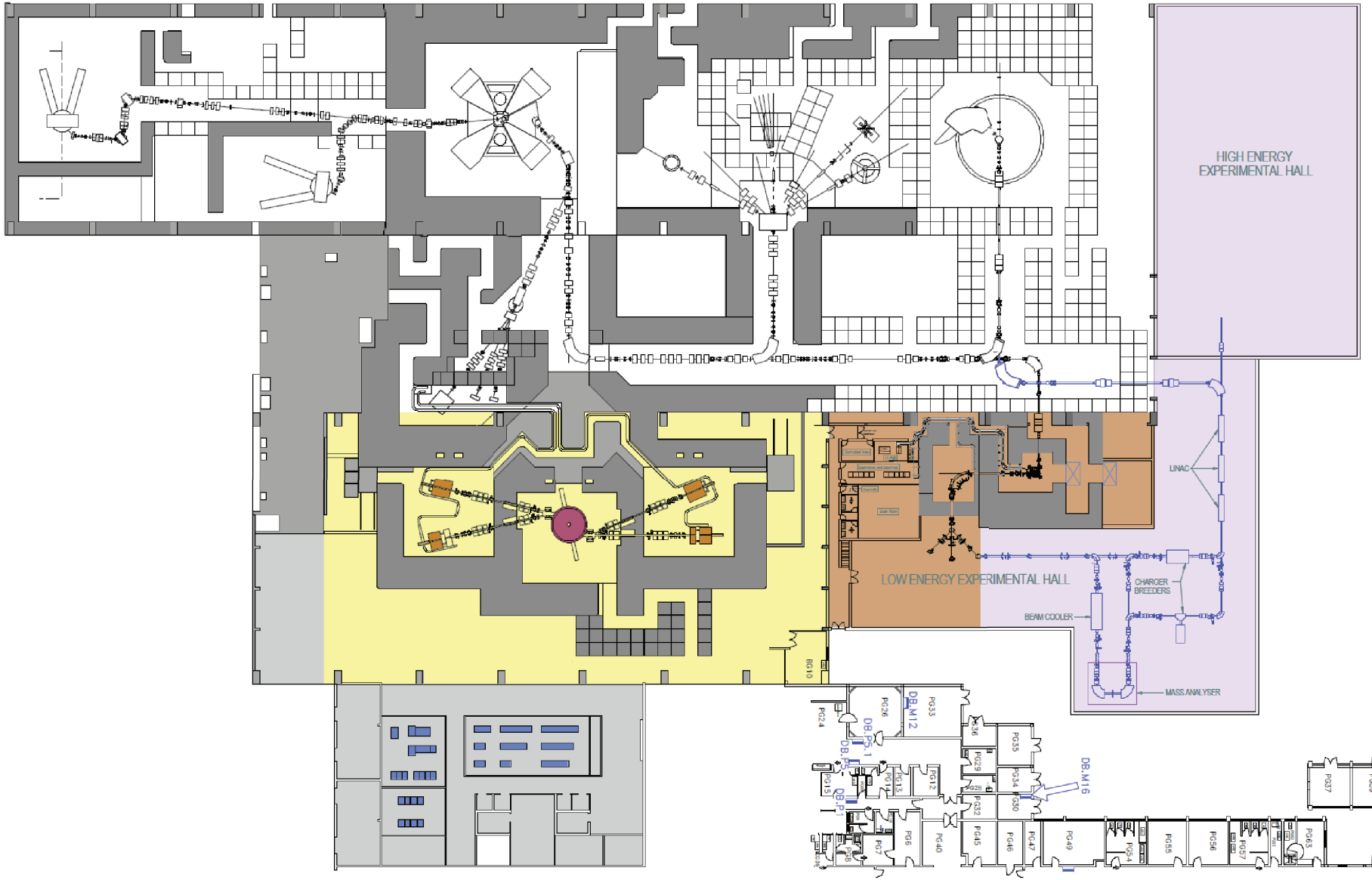



Heater
power
supply
Pyrometers
1.5m
4.5m
Isotope
production vault
Location of
test chamber




Horisontal
Current
60.05
Current
High
Low
Amplitude
Time
2:08:36.793 PM
2/6/2012
2:09:26.793 PM
2/6/2012
2:10:19.089 PM
2/6/2012
% Completed
Upper
0.05
uA
Left
Right
-0.05
uA
0.10
uA
0.01
Lower
BeamSpot
mm
Amplitude

New facilities at iThemba LABS



Thank You