PROPOSED NEW FACILITIES FOR PROTON THERAPY AT iThemba LABS

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Abstract

New facilities, based on a commercial 230-250 MeV cyclotron, for proton therapy are proposed for iThemba LABS (previously National Accelerator Centre, NAC, South Africa). In addition to the existing two vaults for proton therapy, three further vaults will be provided. Four of these vaults will be equipped with, respectively, an iso-centric raster-scanning system, a fixed horizontal line for raster-scanning and two fixed lines for scattering systems enabling treatment from two angles each. Proton beams from the new cyclotron will be switched between the different vaults. It is estimated that about 1000 patients will be treated annually with the new facilities, which will be operated on a commercial basis. The existing 200 MeV cyclotron will be retained for nuclear physics research, production of radionuclides and neutron therapy and will in future also be used for eye treatment with protons in one of the existing vaults for proton therapy. The rationale for and the layout of the facilities are presented.

1 INTRODUCTION

iThemba LABS operates a 200 MeV separated-sector cyclotron, SSC, with two solid-pole injector cyclotrons SPC1 and SPC2 [1-3]. SPC1 has an internal PIG ion source and is used for acceleration of high intensity beams of light ions. Beams of heavy ions, from an ECR ion source, and polarized protons are axially injected into SPC2 for pre-acceleration before injection into the SSC.

Radionuclides and radio-pharmaceuticals are produced for 4 nights per week using an intense 66 MeV proton beam from the SSC with SPC1 as injector. The same beam, but with lower intensity, is also used for neutron therapy for 4 days per week. The beam can be switched within seconds between these two applications. For proton therapy a 200 MeV beam from the SSC with SPC1 as injector has been used for 4 days per week for about 4 years up to the end of 2001. SPC2, which is similar to SPC1, can also be used for neutron and proton therapy applications when SPC1 is out of operation. Beams of light and heavy ions, as well as polarized protons from the SSC, with SPC2 as injector, are utilized for nuclear physics research over weekends. This beam schedule required nine energy changes per week.

Although this cyclotron configuration is very versatile in providing a variety of beams with vastly different properties for various applications, it is also complex to operate and maintain, especially since SPC1 and the SSC are almost 20 years in operation. This poses a serious problem, as resources are limited, and impacts negatively on beam delivery. The number of energy changes per week have therefore been reduced to four, with the result that proton therapy is now scheduled for only two days per week.

Proton therapy commenced with iThemba LABS' 200 MeV beam in September 1993 [4-7]. Since then, 409 patients (about 50 per annum) have been treated. At present, proton therapy can only be undertaken on Mondays and Fridays, which is a limiting factor since not all patients that could potentially benefit from such treatment can be accommodated. The current proton therapy facility at iThemba LABS is designed mainly for the treatment of brain, inter-cranial and base of skull conditions. Furthermore, due to restricted beam time availability, proton therapy can only be undertaken on Mondays and Fridays (on an one shift basis), with the result that fully fractionated treatments cannot be undertaken. With the proposed facility, many more conditions are treatable and fully fractionated treatment will be available.

2 PROPOSED FACILITIES

It is proposed to create a Major Radiation Medicine Centre (MRMC) on the iThemba LABS site by augmenting present facilities in a partnership with the private sector. The present proton therapy facilities at iThemba LABS will be extended by purchasing a stand alone 230-250 MeV proton therapy accelerator and building three new treatment vaults which, with an already existing vault, will enable four treatment stations to operate in parallel as shown in Fig. 1. The minimum energy of 230 MeV for the accelerator is chosen so that deep-seated tumors in all body sites can be reached. A synchrotron and a cyclotron have been considered for the project, and a cyclotron was decided on to allow raster-scanning without taking the duty cycle of the beam into account. The cyclotron will provide proton beams to a

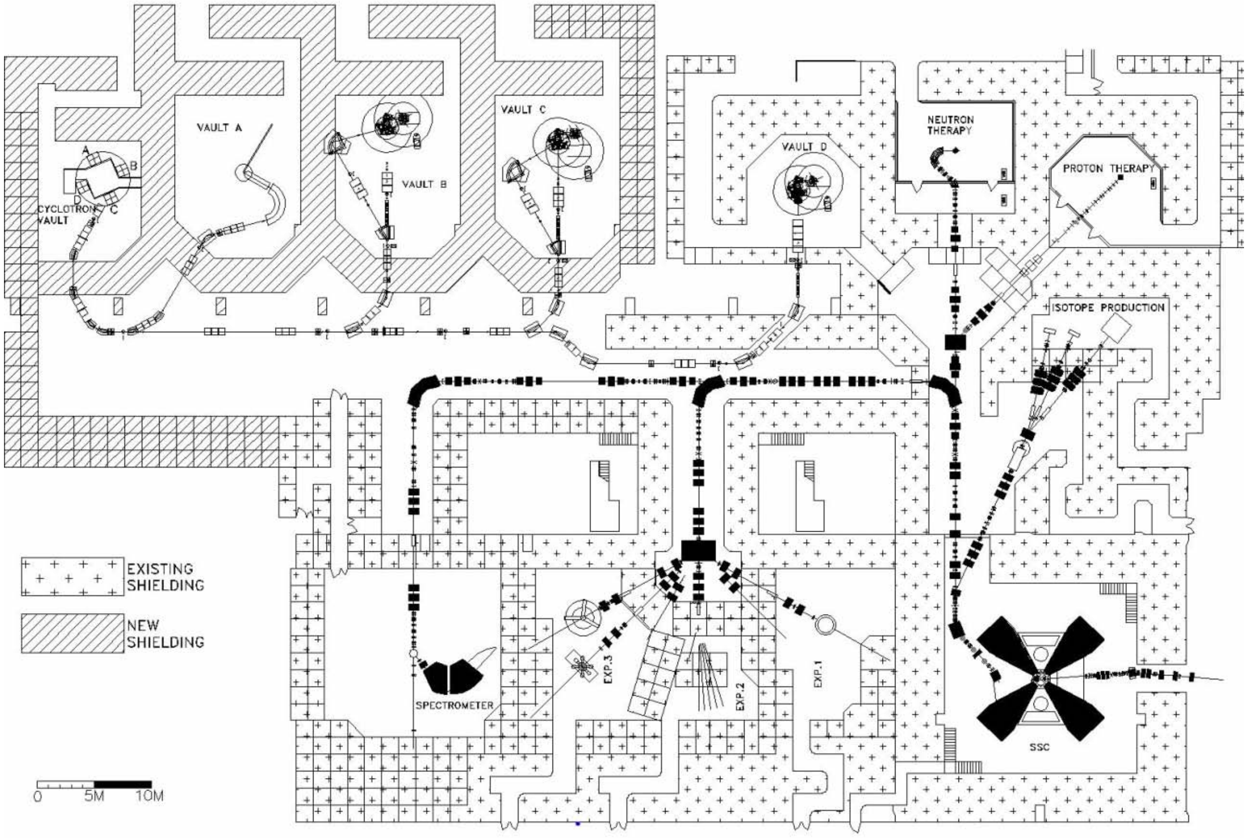


Figure 1: Layout of the proposed extensions to the facilities for therapy at iThemba LABS. A new 230 MeV cyclotron will provide proton beams to a scanning gantry in vault A, two non-orthogonal beamlines, using the scattering technique, in each of vaults B and C and a fixed horizontal beamline in vault D for scanning treatment.

scanning gantry in vault A, two non-orthogonal beamlines, using the scattering technique, in each of vaults B and C and a fixed horizontal beamline in vault D for scanning treatment. The existing hospital will be extended by constructing a double storey building, which will include children's wards, areas for chemotherapy treatment and reception as well as waiting rooms, on its north end. To accommodate the staff, the first floor will also be extended. These facilities can be installed in a simple and ergonomic extension of the present buildings, giving considerable savings over a completely new construction.

Cancer is a major public health problem. In 1995, the National Cancer Registry (NCR) estimated that about one in four people in South Africa will develop cancer in their lifetime. Between 1993 and 1995, an average of 49 939 new cases of cancer per annum were reported to the NCR. The new infrastructure will enable the number of patients that can be treated annually with proton therapy to be increased from 50 to 1000 of which some 400 will be from abroad. Additionally, multi-fractionated treatments become possible, which greatly increases the range of conditions that can be treated and vastly extends the possibilities for clinical research.

The transfer of proton therapy to a stand alone accelerator will release time on the existing separated-sector cyclotron to extend the annual capacity of the present neutron therapy from 100 patients to over 350. Patients can also receive treatment using photons, either at the MRMC or at partner facilities.

Currently physics research is only scheduled for beam time on the weekends, which usually starts at 22h00 on Friday and lasts till 06h00 on Mondays. Moving proton therapy to a dedicated accelerator for proton therapy will allow an extra 24 hours of beam time per week to be allocated to physics

The 66 MeV proton beam used for radionuclide production is currently being increased in intensity by a factor of four. The upgrading of the target stations and the hot cell facilities to manage the increase in radioactivity produced should be completed by the end of 2002. The ability to produce radio-pharmaceuticals at iThemba LABS and the radiochemical skills and facilities available make the proposed MRMC a prime site for an advanced PET facility. This high sensitivity and high resolution imaging system can be used to examine up to 3000 patients per year

The MRMC will also provide the opportunity to establish new protocols, often in collaboration with the other international centres in Boston and the Loma Linda Medical Center in Southern California that will enable clinical research to flourish and to reach the cutting edge of developments in the radiation therapy field. There is an acute shortage of Radiation Medicine expertise in South Africa. The establishment of the new facilities will allow rectification of this situation.

3 COST ESTIMATES

It is estimated that the capital costs of the new proton therapy facilities, extensions to the present buildings to cope with the greatly increased patient throughput, ancillary imaging and other equipment, installation, start-up and training costs as well as costs for the radionuclide facilities upgrade (including PET) will require a total investment of about €61m. The facilities will require about 4 years to be installed and will be operated at optimum level from the beginning of the seventh year at which time the net annual pre-tax income that will be derived from the dedicated proton therapy operation will be approximately €3.2m. This is a conservative estimate which could increase to €5.5m annually depending on international tariffs, patient mix, etc. Furthermore, cost recovery at iThemba LABS will be enhanced by some €0.6m annually as existing costs relative to the hospital and Medical Physics operations will be levied to the proton therapy facility. It is therefore a necessity that patients are charged for treatment. Successful patient accrual is therefore even more vital to this proposal than it would be in other eventualities. That there is a global need and market for the best healthcare is well established. The markets are catered for in advanced countries such as the USA and UK.

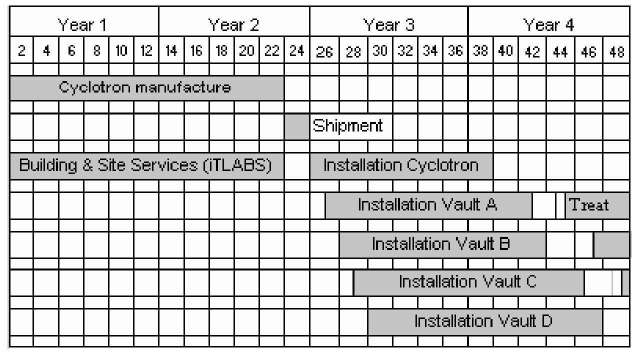
The establishment of the Major Radiation Medical Centre will afford iThemba LABS the opportunity of improving its cost recovery performance. Hospital running costs together with 50% of the current Medical Physics expenses will be recovered, a total of some €0.6m, which will primarily be utilized to replace and purchase capital equipment that is needed given the ageing asset base at iThemba LABS.

4 TIME SCHEDULE

A cyclotron manufacturer indicated that the delivery time for the cyclotron would be about 2 years. This gives iThemba LABS enough time to complete the buildings, infrastructure and site services required for the project. A provisional installation schedule is given in Table 1 below.

From month 19, delivery of various equipment will occur. From this point, staff recruitment will commence. This will ensure that staff acquire training during the commissioning and testing of equipment and familiarise themselves with the operations. By the end of month 40, installations in Vault A should be completed. Beam testing and beam measurements will be conducted from there on. This should be completed by the end of month 44. From the beginning of month 45, patient treatment will commence. A gradual build up of patients is allowed for staff to familiarise themselves with the equipment and techniques. The patient accrual patterns will build up gradually up to month 72, when full capacity of about 100 patients per month will be reached

Table 1: Installation and treatment schedule for the MRMC



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