The CERN Accelerator School

CERN

Centro Radiológico de Aplicações Protônicas

A CAS MEDICAL 2015 Case Study

Group 10

CRAP

Overview

1. Rationale
2. Location
   - Country
   - City
3. Technical details
   - Accelerator
   - Beam Transport Line–Selector
   - Beam Delivery System
4. Facility
   - Facility
   - Operation Schedule
   - Human Resources
5. Investment Plan
   - Installation Budget
   - Operation Budget
   - Budget Summary
6. Planning
   - Commissioning
   - Strategy/Limitations

Business Model

- Commercially available Cyclotron System
- High Beam availability and current
- High number of treatment rooms
- Use “down time” between treatments for radioisotope production/radiography
- Relative low investment $\rightarrow$ High revenue
- Aim for “New Continent” without other hadron facilities competitors

Brazil

1. Population $\gtrsim$ 200M (2014) 5^{th}
2. GDP (PPP) total $\approx$ 3.3 trillion \$ 7^{th}
3. HDI $=$ 0.744 high

worldwide

South America

- Total Population $\gtrsim$ 385M (2011)
- "Relatively" high political/social stability
- Absence of competitors

A lot of potential patients!!

Figure: Brazil's location in SA

São Paulo

- Metropolitan population $\gtrsim$ 20M (2014), largest in the continent.
- Offers multiple synergetical possibilities:
  - 217 Hospitals, largest health care hub in Latin America (*e.g. AEIH, the best in Latin America)*
  - Many universities (*e.g. USP, the best in Latin America*)
  - Multiple Infrastructures (*Intl. Airport, heliports, highways, etc*)

Accelerator

- **Superconducting Isochronous Cyclotron 250 MeV**
  - Continuous Beam (72 MHz)
  - External high current Ion Source
  - Over 1 μA Extracted Current
  - Low Activation

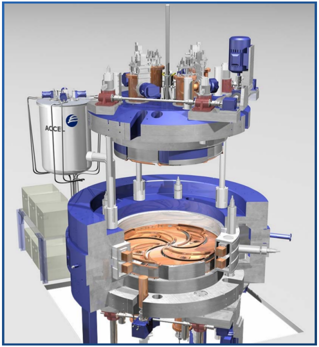
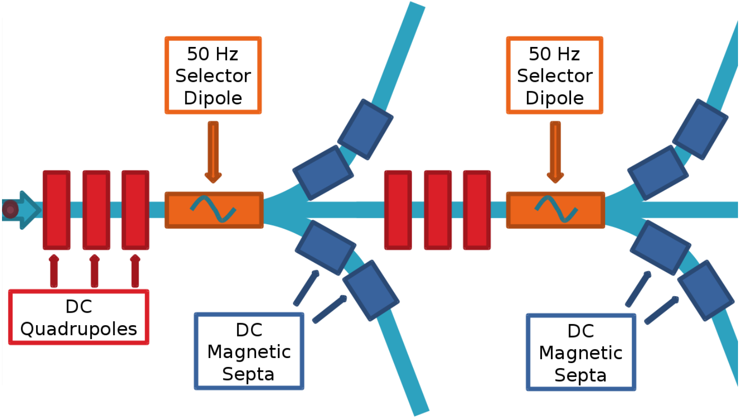


Figure: Varian SC 250 MeV

Isochronous Cyclotron

Characteristic	Value	Unit
Energy	250	MeV
Extracted Current	1000	nA
Emittance	3–5	π μm rad
Extraction Efficiency	80	%
Estat. Intensity Modulation	100	μs
Weight	90	tons
Central & Max B–field	2.4 & 4.0	T
Cryocooler Power	40	kW
Radio Frequency (h=2)	72.8	MHz
RF Power	115	kW

Beam Transport Line–Selector



Beam Delivery System

2×Trifold Dipole Selector for Rooms 1–5

- 50 Hz Selector Magnets (Bipolar)
- Permanent Magnetic – “Septa” on both outer sides

Each Room equipped with rotating degrader:

- Collimator (Beamsize)
- Degrader Rotator (Energy)
- Collimator (divergence)
- Intensity Quad (Intensity)
- Collimator (Intensity)
- Scanning Magnets (continuous)

Therapy Center

Continuous Beam Cyclotron

Fast Beam Switching (50 Hz)

- No scheduling between rooms necessary!
- No waiting for another room to be ready!

4 Treatment rooms

- 3 Gantries
- 1 Horizontal Treatment Line

1 Isotope production/Radiography line

Experimental/Production Room

Default Beam Line

Degrader System, no Energy Selection

Isotope Production focus on:

- ^{89}Y, Rb, Kr $\rightarrow$ ^{92}Sr
- ^{82}Sr $\rightarrow$ ^{82}Rb – PET/SPECT (24 days)
- ^{232}Th(n,γ)^{233}Th(β^-) $\rightarrow$ ^{233}Pa(β^-) $\rightarrow$ ^{233}U(α) $\rightarrow$ ^{229}Th(α) $\rightarrow$ ^{225}Ra(β^-)^{225}Ac(α) – Carrier Molecules, Leukemia (10 days)

Neutron target for radiography

- Tungsten/Uranium Target

Building Layout

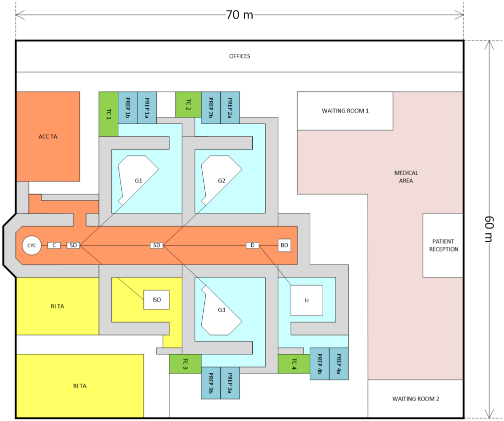


Figure: CRAP floorplan

Operation Schedule

- 2×8h Medical Shifts (including 2h QA) 5 days a week
- Bi–weekly Maintenance Intervention on the weekend
- Research Beam time bi–weekly on the weekend
- Parasitic Isotope Production

Patient Schedule

- 15 minutes in Irradiation room
- 20–30 minutes in Preparation room

Technical Staff	23
Operators & Technicians	18
External Service Personnel	3
Accelerator Supervisor	2

Medical Staff	43
Nurses	20
RTT	10
Medical Physicists	8
Medical Doctors	5

Administration	10

Total	76

Initial Cost

1	Cyclotron	15M€
3	Gantry	21M€
4	Patient Positioning System	1M€
1	Experimental Room Equipment	1M€
5	Degrading System+Collimators	1M€
1	Room Selector System	0.75M€
1	Beam Lines from Cyclotron to Irradiation rooms	10M€
5	DDS/(x,y) chamber/I counter/scanning system	7.5M€
-	Building	50M€
-	Software	1M€
-	IT external Service Contracts	2M€
	SubTotal	≈ **111.25M€**

Yearly Cost

-	Cyclotron	2M€
3	Gantries	0.5M€
-	Electricity	0.78M€
-	Facility	0.5M€
-	Spare Parts	2M€
76	HR (earning an average 80k€)	≈ 6M€
-	IT Software Licenses	0.25M€
-	TPS Licenses	1M€
	SubTotal	≈ **13M€**

Financial Viability

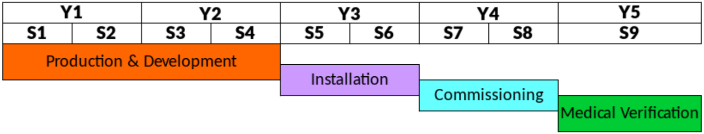
Safety Budget	2M€
Revenue/patient	15k€
→ Revenue/Year	24M€
Isotope Income	≈ 150k€
Operation Cost/year	13M€

≈ 15 Years to pay back investment

Patient estimation data

minutes per treatment: 5
hours/day for treatment: 14
treatments a day: 168
assuming 80% outcome: 134
treatment days: 240
treatments per year: 32160
fractions/patient: 20
patients/year ≈ 1600

Timeline


Y1
Y2
Y3
Y4
Y5
S1
S2
S3
S4
S5
S6
S7
S8
S9
Production & Development
Installation
Commissioning
Medical Verification

Strategical Advantages

- High Patient throughput
- Simultaneous Patient treatment
- No Room scheduling needed

Drawbacks

- Protons Only
- Low Energy (research)
- Low intensities at low Energies (Isotope)