Case Study Work
Group 5

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What we want

• build the first particle therapy facility in our country Neverland

• modular machine which could be duplicated in smaller solution

• a treatment facility and a research user facility
Our choice is a cyclinac

• to treat with protons and carbon ions

• to have 5 treatment rooms

• to have 1 room as user-facility purpose for clinical and non clinical research in which we will also provide helium and oxygen ions

• a modular and scalable design to improve its commissioning
THE SLUG CYCLINAC FACILITY

Building dimension: 70 m x 25 m

Control room, data center, PCO and klystron on the upper floor
Why the SLUG cyclinac?

Compact and modular design

- Cyclotron diameter: 6m
- Total Linac length: 22m
- Smaller and cheaper bunker!
- 3 phases of commissioning!
Why the SLUG cyclinac?

Beam time profile

- Active scanning system
- Spot-Scan: 4D Multipainting
- No carbon ions degrader!
- Time & count driven DDS!
- Short treatments! (<5 min.)
- Moving organs!

<table>
<thead>
<tr>
<th>Accelerator</th>
<th>The beam is always present?</th>
<th>The energy is electronically adjusted?</th>
<th>What is the time to vary $E_{max}$?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclotrons</td>
<td>Yes</td>
<td>No</td>
<td>$&gt;$50 ms</td>
</tr>
<tr>
<td>Synchrotrons</td>
<td>No</td>
<td>Yes</td>
<td>1 s</td>
</tr>
<tr>
<td>Cyclinaes</td>
<td>Yes</td>
<td>Yes</td>
<td>1 ms</td>
</tr>
</tbody>
</table>

Particle/pulse precision: 3%

Spot size (FWHM): 12 mm @protons 173 MeV
5 mm @carbon ion 330 MeV
Technical specification

- **3+1 EBIS-SC Sources:**
  - Species: $\text{H}_2^+$, $\text{C}_6^+$, [ $\text{O}^{8+}, \text{He}^{2+}$ ]
  - Vertical injection
  - Beam intensity: $3.5 \times 10^{11}$/s @carbon ions – $1.1 \times 10^{11}$/s @protons
  - Repetition rate: 100 Hz / source

- **Cyclotron:** [ commercially available ]
  - Type: isochronous
  - Output beam energy: 150 MeV/u
  - Weight: 200 tons
  - Diameter: 6m
  - Magnet rigidity: 3.92 Tm
  - RF harmonic: 98 MHz
  - RF power supply: 110 kW

- **Linac:**
  - Full length: 22 m
  - RF: 5.7 GHz C-band standing-wave
  - Klystron power: 13 x 12 MW
  - Repetition rate: 300 Hz

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**Beam energy precision:** 250 keV
TR-1 single room facility

Beam energy: 70 – 150 MeV @protons

Beam range: 5 – 15 cm in H2O @protons

Beam rigidity: 3.67 Tm (before the stripper) 
1.2 – 1.84 Tm (after the stripper)

Nozzle equipment: 2 stripe detectors, 2 ICs, range shifter

Equipment: robot system with CBCT

Treatment type: H&N, central nervous system, breast, eyes, sarcoma and skin tumors
TR-2 and TR-3

Beam energy:
70 – 250 MeV @protons

Beam range:
5 – 37 cm in H2O @protons

Beam rigidity:
3.67 – 4.86 Tm (before the stripper)
1.2 – 2.4 Tm (after the stripper)

Nozzle equipment: 2 stripe detectors, 2 ICs, range shifter

Equipment: robot system with CBCT

Treatment type:
H&N, central nervous system, breast, eyes, sarcoma, skin, rectum, esophageal, uterus tumors
TR-4 and TR-5

Beam energy:
70 – 250 MeV @protons
150 – 400 MeV/u @carbon ions

Beam range:
5 – 37 cm in H2O @protons
2 – 27 cm in H2O @carbon ions

Beam rigidity:
3.67 – 6.36 Tm (before the stripper)
1.2 – 1.84 Tm (after the stripper only p+)

Nozzle equipment: 2 stripe detectors, 2 lCs, range shifter, ridge filter

Equipment: robot system and 4DCT

Treatment type:
H&N, central nervous system, breast, eyes, sarcoma, skin, rectum, esophageal, uterus and lung tumors
ER user facility

Beam energy:
- 70 – 400 MeV protons
- 150 – 400 MeV/u helium
- 150 – 400 MeV/u carbon ions
- 150 – 400 MeV/u oxygen

Beam range:
- 5 – 82 cm in H2O @protons and helium
- 2 – 27 cm in H2O @carbon ions
- 3 – 20 cm in H2O @carbon ions

Beam rigidity:
- 3.67 – 6.36 Tm (before the stripper)
- 1.2 – 1.84 Tm (after the stripper only p+)

Nozzle equipment: 2 stripes detectors, 2 ICs, range shifter, ridge filter

Research: QA, beam hardness, radiobiology, proton RX, etc...
Patients capacity

• Number of patients per year: about 2100

• Assumed number of fractions: 10 to 25 fractions

• Number of fields per fraction: 1 to 4

• Time needed per patient handling: 10 min

• Time dedicated to treatments: 4.5 h / patient

• Machine development and maintenance: weekends and 2 weeks / year
Time line after final design

• Construction: 2 years

• Accelerator commissioning: 2 + 2 + 1.5 years

• Beam qualification: 8 months

• Clinical trials: 1 year
Financial framework

### Annual Revenue
- Income by imbursement fees: **42 Mio €**
  (2100 patients for 20,000€)
- Research funding: **3 Mio €** (depending on project amount)

### Annual Expenses
- Employees: **9.6 Mio €** (70 Workers)
- Facility maintenance: **2 Mio €**
- Income tax: **10.5 Mio €**
- Initial interest: **7.5 Mio €** (5% of loan)

<table>
<thead>
<tr>
<th>Elements</th>
<th>Cost (Mio Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Estate</td>
<td>40</td>
</tr>
<tr>
<td>4 Ion Sources</td>
<td>13</td>
</tr>
<tr>
<td>1 Cyclotron</td>
<td>30</td>
</tr>
<tr>
<td>2 Linacs</td>
<td>50</td>
</tr>
<tr>
<td>15 Dipoles 45deg + PCO</td>
<td>8</td>
</tr>
<tr>
<td>30 Quad + PCO</td>
<td>3</td>
</tr>
<tr>
<td>2 Dipole 90Deg + PCO</td>
<td>2</td>
</tr>
<tr>
<td>8 Scanning Magnets + PCO</td>
<td>2</td>
</tr>
<tr>
<td>200m of Beam pipes + Vacuum system</td>
<td>2.5</td>
</tr>
<tr>
<td>Beam Diagnostics</td>
<td>5</td>
</tr>
<tr>
<td>6 DDS + DDI</td>
<td>2.5</td>
</tr>
<tr>
<td>6 Irradiation Room equipment</td>
<td>15</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>173</strong></td>
</tr>
</tbody>
</table>
Thank you for your attention!

Happy birthday Martina!!!

Vielen Dank fur Ihre Aufmerksamkeit!

Merci pour votre attention!