Kingdom of Farland

Princess Peach
Particle Therapy Center

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CAS - Group 3
Vösendorf – Austria
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Kingdom of Farland

- Developing country, pop. 67 million over 510,000 km$^2$ in SE Asia
- GDP per capita = $11,000 (PPP) , $6500 (nominal)
- Already experienced with latest photon radiotherapy equipment (TrueBeam, Cyberknife, TomoTherapy, 4DCT/PETCT/MRI simulation)

<table>
<thead>
<tr>
<th>Disease sites</th>
<th>No. w RT</th>
<th>% for PT</th>
<th>No. for PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>650</td>
<td>40</td>
<td>260</td>
</tr>
<tr>
<td>Head/Neck</td>
<td>2000</td>
<td>40-75</td>
<td>1150</td>
</tr>
<tr>
<td>Lung/Thorax</td>
<td>1600</td>
<td>72</td>
<td>1152</td>
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<tr>
<td>Breast</td>
<td>2575</td>
<td>10</td>
<td>258</td>
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<tr>
<td>GI tract</td>
<td>1500</td>
<td>18-50</td>
<td>510</td>
</tr>
<tr>
<td>Gyne</td>
<td>2000</td>
<td>8</td>
<td>160</td>
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<tr>
<td>Others</td>
<td>2500</td>
<td>15</td>
<td>375</td>
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<tr>
<td>Pediatric</td>
<td>380</td>
<td>60</td>
<td>228</td>
</tr>
</tbody>
</table>

~4000 p. could benefit from particle therapy

At first, target of 1000 p/y (25%)
Clinical needs

- Cost-effective solution focused mainly on healthcare service
- Operation time 16 h/d, 240 d/y amounts to 30,000 fractions/year

<table>
<thead>
<tr>
<th>Type of Particle(s)</th>
<th>Proton, Helium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main treatment sites</td>
<td>Lung, Upper abdomen, Brain, Eye and Spine</td>
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<tr>
<td>Range</td>
<td>4 – 32 cm in water</td>
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<tr>
<td>Beam delivery</td>
<td><strong>Pencil beam scanning</strong> Beam spot size : 3 mm at Maximum energy Ability to equip with respiratory gating Field size : 20 x 20 cm Fixed beam with various angles (but planned for future gantry installation)</td>
</tr>
<tr>
<td>Dose rate</td>
<td>Minimum 2 Gy/min/l, up to 5 Gy/min/l</td>
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</tbody>
</table>
Why use $\text{He}^{2+}$ ions?

- Reduced beam broadening compared to $\text{p}^+$ (sharper beam penumbra)
- Small fragmentation tail (compared to Carbon)
- Simple RBE calculations (low LET like $\text{p}$)
Comparing H+ to He²⁺

Figure 6. Top view on lateral dimension and energy deposition as function of range for a 200 MeV proton beam.

Figure 7. Top view on lateral dimension and energy deposition as function of range for a 200 MeV/A helium ion beam.

« Comparison of basic features of proton and helium ion pencil beams in water using GATE »
Technical choices

- Proven technology with expertise available in the region.
- Commercially available with competition
- Limited ancillary equipment
- Simple operation
- Aiming first at patient treatment
- Low maintenance and high MTBF

-> Cyclotron
Technical choices

• 3 treatment rooms.
• Auxiliary shared clinical rooms:
  – patient preparation and immobilisation, one per IR
  – 1 dedicated and shared for imagery
    (X-Ray and PET/CT, MRI available in UH)
  – Interconnected with shuttle path
• Auxiliary technical rooms
  – TPS
  – Control rooms, one per IR
Possible layout

• Cyclotron sized for p and He; requires local shielding and separate room
• Two sources with T connection on top of cyclotron, above shielding, and axial vertical injection
• Simple commercially available ECR sources for robustness and ease of operation;
• $\text{H}_2^+$ and $\text{He}^{2+}$ are similar from beam dynamics point of view. $\text{H}_2^+$ is stripped to 2 protons in a foil at the exit of cyclotron.
• Beam lines as short as possible
3 IR stacked vertically

2 ECR sources in T array with vertical axial injection
Angular Coverage

• Three stacked rooms provide effective combined angular coverage

• Patient can be treated in different rooms

• Comfort of couch at +15° is limited.
3D model rendering of the PPPTC (Cyclotron and patient not to scale)
Beam Instrumentation

Cyclotron
• Radial Beam Probe: destructive Profile and Intensity monitor for intensity measurement and profile evaluation with camera

Beam Transport line
• Faraday Cups: Destructive Intensity measurement at several key points
• Scintillating cameras: destructive Profile monitor
• Current Transformers: Non destructive Intensity measurement
• Collimators for beam shaping in phase space
• Degraders: Graphite wedges. Allows energy range of 70 – 230 MeV
• Slit plates: for energy selection
• Scanning magnets at the downstream end (nozzle)
Patient positioning and verification

Patient positioning with floor mounted robotic arm, can be tilted +/- 15°

Positioning verification with

- Optical system (IR markers attached to patient or mask, ceiling mounted camera)
- X-Ray system (in-floor sources, ceiling mounted detector panels)
Patient workflow

1.) Immobilisation of the patient in preparation room (one per treatment room)
2.) Transport of the patient into the treatment room with a shuttle
3.) Patient positioning and positioning verification
4.) Irradiation
5.) Optional: Dose verification after treatment in separate room equipped with PET-CT (one for all)
Limitations

• Fixed beamlines and reduced angular coverage

• Limited penetration depth, hence no transmission imaging

• In-room imaging limited to position verification

• Very limited research beyond clinical studies with He beams.
# Cost and Reimbursement

- Land and facility capital investment generously offered by the King to the kingdom
- Limited operating costs by adjoining the center to the RT center of the University Hospital
- Need to cover only operating costs

<table>
<thead>
<tr>
<th>Group</th>
<th>Definition</th>
<th>Reimbursement</th>
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<tbody>
<tr>
<td>I</td>
<td>Absolute indication. Survival benefit from clinical evidences.</td>
<td><strong>Fully covered</strong></td>
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<tr>
<td>II</td>
<td>Relative indication. Possible survival or QOL/Toxicities benefit from dosimetric study.</td>
<td>50% covered or Fully covered with clinical trial</td>
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<tr>
<td>III</td>
<td>No indication. Neither survival nor QOL/Toxicities benefit from clinical evidences.</td>
<td>Not permitted for PT in PPPTC</td>
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<td>IV</td>
<td>Foreigner, Private practice or Prioritized on waiting list</td>
<td>Not covered + 20% additional price</td>
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## Project Timeline

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<td>Clinical acceptance</td>
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<td>First patient treatment</td>
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Ready to “hit those bad tumours very hard with ion particles” at the Princess Peach Particle Therapy Center