CERN Accelerator School
Accelerators for Medical Applications 2015

Case Study
the KingRing facility

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Outline

- Location and Motivation.
- Patient Workflow Estimation.
- Main parameters.

- Layout of the **KingRing** facility
  - Ion sources.
  - Linac Injector.
  - Synchrotronility.
  - Extraction and delivery

- Summary
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Location and Motivation

- **Saudi Arabia (Dammam)**
  - Founding: Saudi Arabia government + a special contribution from local universities.
  - Goal: Developing expertise in accelerators for medical applications and physics research.

- Population: **30 M**
  - 1% cancer to be treated per year;
  - 20% treated with radiotherapy;
  - 15% radio-resistance.

- Long prospective: treating **9 k patients/y.**
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Patient Workflow Estimation

→ Assuming:

- 8 to 20 h = 12 working hours for patients;
- 5 days/wk treatment + 1 day/wk maintenance + 1 day/wk + daily QA and nights for study and development;
- 3 wk/y + 2 wk/y holidays for Ramadam and Pilgrim season (used also for maintenance + 1 wk/y maintenance;
- 30 min/irradiation fraction;
- 20 fractions/patient;
- 3 rooms (2 Gantries) + 1 for experiment.

46 wk/y irradiation ➔ 828 patients /y
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Main parameters

➡ **Proton beam:**
  - In the range of $1\times10^10$ p/spill to patient and 10 times to experimental room.
  - 250 MeV

➡ **Carbon beam:**
  - In the range of $5\times10^8$ C/spill to patient
  - 400 MeV/u
  - Pencil beam with scanning magnets (20x20 cm$^2$)
  - About 1 mm characteristic size at patient

➡ 2 Gantries (one for proton and one for carbon ions)

➡ No superconductive magnets (limited access to LHe).
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Layout of the KingRing facility

Extraction system

Synchrotron

Linac Injector

Sources

Gantry

Gantry

Gantry

Research line

For experiment

Treatment room 1

Treatment room 2

Treatment room 3
Ion source 1:
- Supernanogun (ECR) 14,5 GHz
- mostly for proton
- in reserve for carbon ions

Ion source 2 (similar than no. 1)
- Supernanogun 14,5 GHz
- mostly carbon ions
- in reserve for proton

Ion source 3
- Experimental ECR-ionsource for research purposes.

Ion source 4
- One free space to install and test new ion sources.
→ Energy up to 7 MeV/u

→ $f = 352$ MHz (commercial tetrode at this freq as power supply, 1.05 M€)

→ RFQ (up to 500 keV, bunched)

→ DTL (up to 7 MeV, injector to synchrotron)
Injection:
with septum magnet at energy of 7 MeV/u.

Magnetic Rigidity:
- 250 MeV protons: 2.5 T·m
- 400 MeV/u C^{6+} ions: 6.6 T·m
- 250 MeV/u He^{2+} ions: 5 T·m

Dimensions:
given by carbon ions requirements, since they are more rigid;
- Max bending radius at 2 T: 3.3 m
- Dipole magnets consist of 50% of the synchrotron, therefore
  \( R = 6.6 \text{ m} \rightarrow 41 \text{ m of circumference} \)
Components

- 2 T dipoles: bending magnets
- Quadrupoles: in FODO lattices for beam focusing
- Magnet correctors (sextupoles, octupoles)
- Septum magnets: injection/extraction
- RF tank: 1 acceleration point per turn
- Beam diagnostics

Acceleration parameters

<table>
<thead>
<tr>
<th>Particle</th>
<th>Energy [MeV/u]</th>
<th>Magnetic field [T]</th>
<th>RF frequency [kHz]</th>
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<td>0.12</td>
<td>860</td>
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<tr>
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<td>250</td>
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<td>400</td>
<td>2</td>
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<tr>
<td></td>
<td>250</td>
<td>1.5</td>
<td>4390</td>
</tr>
</tbody>
</table>
**Extraction and delivery**

- **Extraction:**
  - To start with: slow extraction (1 to 10s) with 3rd resonance excitation.
  - RF – KO with energy modulations and intensity adaptation will be developed with the aim of delivering the whole dose with one extraction. We should gain in stability and in time.

- **Delivery with on-line monitoring:**
  - Besides standard delivery dose monitoring
  - X-rays
  - PET (PET + CT during preparation)
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Summary and Future Plans

⇒ **KingRing** will be located in Saudi Arabia.

⇒ It will serve the whole country and Middle East regions.

⇒ Costs covered by SA government (estimated in the order of 500 M€).

⇒ Construction time 3 to 4 y.

⇒ Commissioning 2 y (training necessary) + 1 y for clinical trials.

⇒ Full reimbursement by state based health assistance.
Thank you - the KingRing team
Layout of the KingRing facility
- **Saudi Arabia (Dammam)** with government money plus a special contribution from South Arabia for developing expertise in accelerators for medical applications and physics research.

- We have to account for 30M people. With the assumptions of 1% cancer to be treated per y, of which 20% treated with radiotherapy, and 15% radioresistance, we have to aim at treating 9k patients/y.