Overview and Status of the Austrian Particle Therapy Facility
MedAustron

Peter Urschütz
MedAustron

- Centre for ion beam therapy and non-clinical research
- Treatment of 1200 patients/year in full operation
- Worldwide the 6th combined centre for ion beam therapy with protons and carbon ions

- Founded in 2007 as „EBG MedAustron GmbH“
  - in indirect ownership of the federal state of Lower Austria
Financing

- Investment volume: € 200 million

- Financing partners:
  - Republic of Austria
  - Federal State of Lower Austria
  - City of Wr. Neustadt
Location

- Wiener Neustadt, approx. 50 km southern of Vienna
- 40,000 inhabitants
# Radiotherapy

<table>
<thead>
<tr>
<th>Accelerator type</th>
<th>Conventional Radiotherapy</th>
<th>Proton Therapy</th>
<th>Ion Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accelerator type</strong></td>
<td>Electron Linac</td>
<td>Cyclotron</td>
<td>Synchrotron</td>
</tr>
<tr>
<td><strong>Particle type</strong></td>
<td>Electrons, photons</td>
<td>Protons</td>
<td>Ions (protons, carbon ions)</td>
</tr>
<tr>
<td># Austria</td>
<td>&gt; 40</td>
<td>0</td>
<td>1 (2016)</td>
</tr>
<tr>
<td># World</td>
<td>x000</td>
<td>~ 45</td>
<td>6 (incl. MedAustron)</td>
</tr>
</tbody>
</table>
Ion beam therapy – innovative form of radiotherapy

Main benefit: protection of surrounding healthy tissue.

Treatment of tumors next to organs at risk

Huge benefit specially for kids.
Carbon ions – differences compared to protons

- Higher and energy dependent LET
- Higher and energy dependent RBE
- Less scattering
- Lower dependency on the cell cycle
- Increased effectiveness in case of radiation resistant tumor (hypoxic tumors)
- Improved dose conformity
- Potentially lower fractionation scheme
- Increased fragmentation tail
- Less experience compared to protons
- Lower acceptance in the community
The MedAustron facility

Irradiation Rooms
Treatment / Clinical Research:
- 4 Proton Gantry
- 3 Horizontal fixed beam
- 2 Horizontal and vertical fixed beam

Non-clinical Research:
- 1 Horizontal fixed beam

Ion Sources
Linear Accelerator
Synchrotron
Irradiation room configuration

- **Horizontal Fixed Beam**
  - Protons & Carbon Ions
  - Patient Treatment

- **Horizontal and Vertical Fixed Beam**
  - Protons & Carbon Ions
  - Patient Treatment

- **Gantry**
  - Protons
  - Patient Treatment

- **Horizontal Fixed Beam**
  - Protons & Carbon Ions
  - Non-clinical Research
Irradiation concept

- active energy selection
  - -> penetration depth
- transverse pencil beam scanning
- online beam monitoring

- no patient specific passive devices!

Courtesy of GSI
Source room

- Ion sources to produce protons or carbon ions
- Back-up source
Linear accelerator

Pre-acceleration and beam shaping to meet injection conditions of synchrotron
The Injector

- Generation of protons and $C^{6+}$
- Acceleration of beam to 7 MeV/u

- Stripper foil ($H_3^+$ to p, $C_4^+$ to $C_6^+$)
Synchrotron

Beam from Injector (7 MeV/u)

Beam to Patient

- Acceleration of beams to desired extraction energy
- Active energy selection:
  - 255 selectable energy steps (steps of 1 – 2 mm)
  - p: 60 – 250 MeV (NCR: 800 MeV)
  - C: 120 – 400 MeV/u
- Ramp speed: 0.5 s to highest energy
- Extraction time: 1 – 10 s

approx. 25m
The synchrotron

Center-piece of the accelerator
Synchrotron

Typical cycle for a synchrotron for medical use with slow extraction.

- Beam structure: pulsed, energy and intensity variable
Synchrotron hall
Extraction line

guiding the beam
into the 4 irradiation rooms
Transverse pencil beam scanning: beam size: mm range (FWHM in vacuum)

Fast magnetic deflection: scanning speed > 20 m/s

One iso-energy slice irradiated with approx. one extracted beam pulse (spill of 1 – 10 s)
Particle accelerator – key figures

- developed in close cooperation with CERN
- more than 1,000 large components
- 220 manufacturers from 23 countries
- diameter of the synchrotron: 25 m
- more than 100 km of cables
- power consumption: 5 MW (approx. 10,000 households)
Beam parameters

Particles
- protons, carbon ions

Energy
- Clinical energies: p: 60-250 MeV; C6+: 120-400 MeV/u -> 3-37 (p)/27 (C) cm penetration depth in water
- IR1: clinical energies + up to 800 MeV for protons

Intensity
- Per spill: 1 * 10^{10} (p) / 4 * 10^{8} (C)
- 4 different intensity levels

Size
- 4 sizes: 4, 6, 8, 10 mm FWHM [in vacuum]
- Scanning field: 20x20 cm² (IR1-3), 12x20 cm² (IR4)

Beam delivery precision
- < 0.5 mm
100.000 different beam combinations...

Accelerator is able to generate:

- 2 ion species
- 255 different energies
- 4 beam sizes
- 4 intensities
- 8 extraction lengths

- **65'280** Beam combinations per beam line
- Gantry: various angles need to be considered
- Non-clinical research: extended energy range

⇒ huge amount of commissioning work

Example for table to select a beam combination
Comparison Synchrotron - Cyclotron

- Energy: active energy selection vs. fixed energy (+ degrader)
- Radiation protection: small vs. large efforts
- Beam currents: low vs. high
- Ion species: multiple ions vs. protons only
- Footprint: large vs. small
- Cost: high vs. low
- Vendors: no commercial systems (Europe) vs. multiple vendors
The proton gantry

- rotating the beam 180° around the patient
- allows irradiation from various angles
- based on the PSI-2-Gantry, further developed by MedAustron

- total weight: 220 t
- swing diametre: 7,5 m
- precision: < 0,1°
- isocentre: < 0,3 mm
The proton gantry
Gantry treatment room
CE labelled medical product

- Ion Sources
- Linear Accelerator
- Synchrotron
- Beam Distribution
- Beam Outlet for Nonclinical Research & Engineering Applications
- Accelerator Control System (Main Control Room)

Power Supplies/Device Control Units (2.OG)

Dose Delivery System

Clinical Beamlines IR2: horizontal 1 (A) and vertical (B)

Clinical Beamline IR3: horizontal 2 (C)

Clinical Beamline IR4: Gantry Beamline (D)

MAPTA Treatment Control Panel (Local Control Rooms 1 to 4)

according to Medical Device Directive (MDD)
Irradiation room

- Patient treatment is controlled and monitored by the Oncology Information System (OIS)
Robotic patient positioning system

- ceiling-mounted
- 7 degrees of freedom
- non-isocentric treatment
- tracking position of the bench with optical tracking system
- positioning accuracy: < 0.5 mm
Patient position verification system

- Flat panel and X-ray tube rotatable around the ring, couchmounted
- Fast flat panel detector (30 Hz framerate)
- Single source dual energy X-ray (60, 120 kV)
- Large clearance (78 cm ring)
- 2D, 3D imaging
- Cone beam CT
Patient positioning and verification system
MedAustron: project timeline and status
Construction
2011- 2012 (18 months)
Construction
2011- 2012 (18 months)
Oct 2012: Moving in
Accelerator installation 2013 - 2014

First beam in IR3 in Oct. 2014
Accelerator commissioning 2015

- work in progress
- intensity, beam position and FWHM beam size over extracted spill measured in HEBT
Accelerator commissioning 2015

- work in progress
- beam measured by detectors of dose delivery system
Penetration depth

Particle energy successfully adjusted within a single iteration round.
Beam size

measured at isocenter

beam size and symmetry adjusted within a single iteration round.
Recent commissioning results

250 MeV Scanned Proton

FWHM x: 7.0 mm
FWHM y: 7.0 mm
Recent commissioning results

250 MeV Scanned Proton

FWHM x: 7.0 mm
FWHM y: 7.0 mm

Video
Installation of vertical beam line

- Vertical beam line installed in Q4 2015
- Beam commissioning in 2017
Remaining steps towards 1\textsuperscript{st} patient treatment

- Finalisation of the proton beam commissioning for horizontal fixed beam lines
  - Fine tuning of beams
  - Coverage of full parameter space (different energies, intensities, etc...)
- System integration (complete workflow)
- Interlock and error management
- Verification and validation test phase
- Technical documentation and regulatory aspects
- Medical physics: base data measurements (TPS)
- End to end tests
1\textsuperscript{st} patient treatment in 2016

- 2016: first patient treatment with protons (horizontal fixed beam lines)
- 2016: provide beams for non clinical research
- 2017 – 20:
  - Commissioning of further beam lines,
  - Carbon ions,
  - Gantry
  - enhance functionalities, performance increase
- 2020/21: full operation
Thank you for your attention!