MedAustron

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

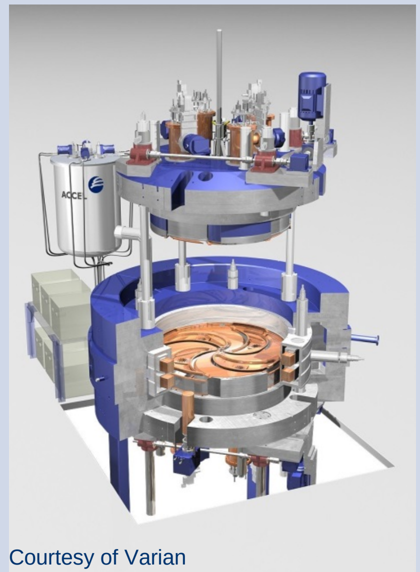
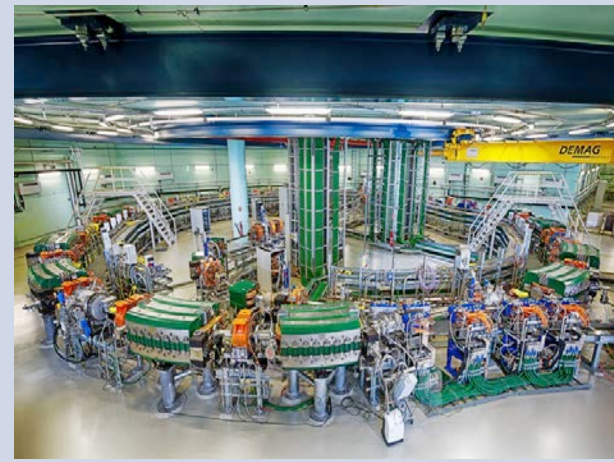
- Investment volume: € 200 million

- 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

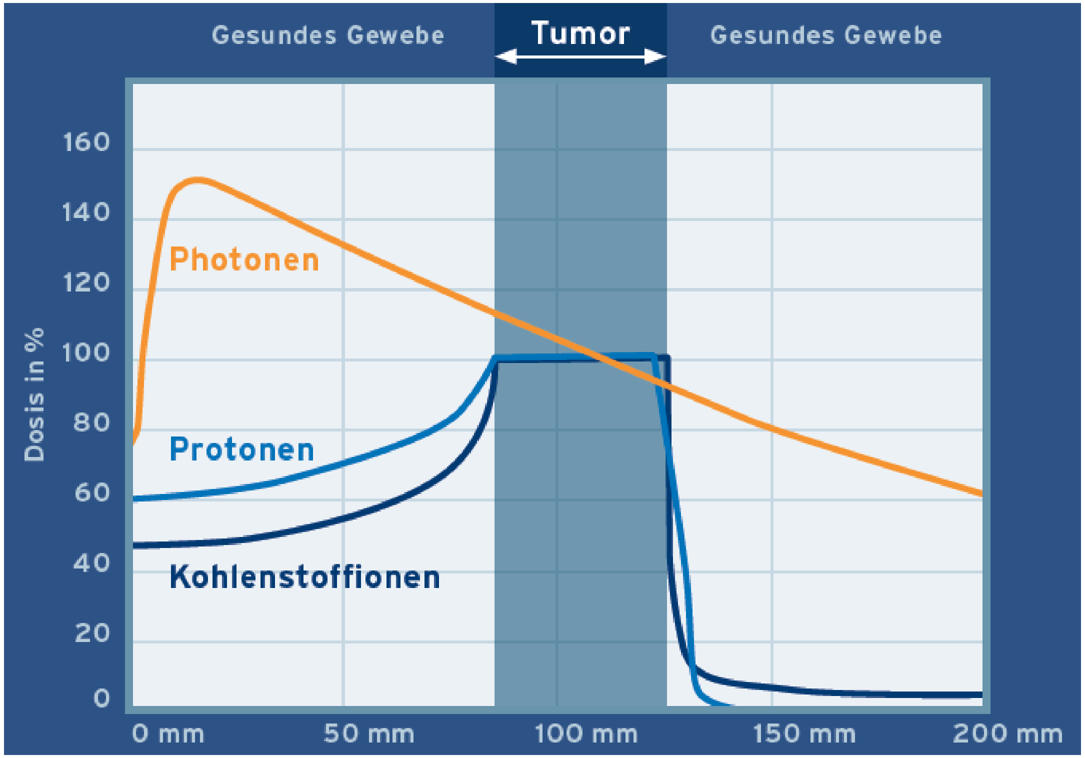
	Conventional Radiotherapy	Proton Therapy	Ion Therapy
Accelerator type	Electron Linac  Courtesy of Varian	Cyclotron  Courtesy of Varian	Synchrotron 
Particle type	Electrons, photons	Protons	Ions (protons, carbon ions)
# Austria	> 40	0	1 (2016)
# World	x000	~ 45	6 (incl. MedAustron)

Ion beam therapy – innovative form of radiotherapy

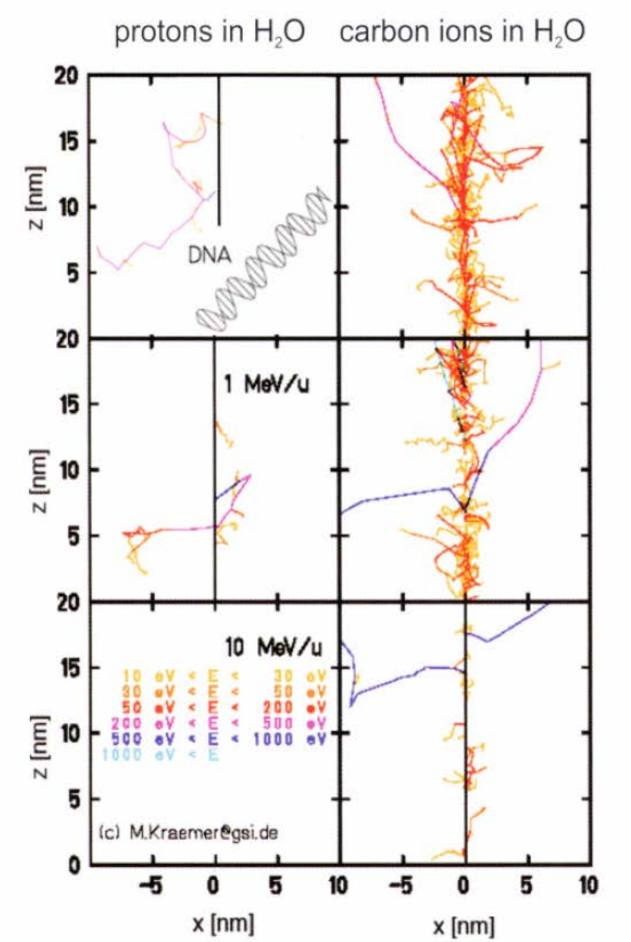
Main benefit: protection of surrounding healthy tissue.

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

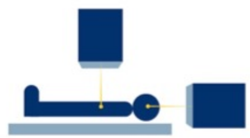
Irradiation room configuration

Horizontal Fixed Beam

p c

Protons &
Carbon Ions

Patient Treatment



Horizontal and
Vertical Fixed Beam

p c

Protons &
Carbon Ions

Patient Treatment

Gantry

p

Protons

Patient Treatment

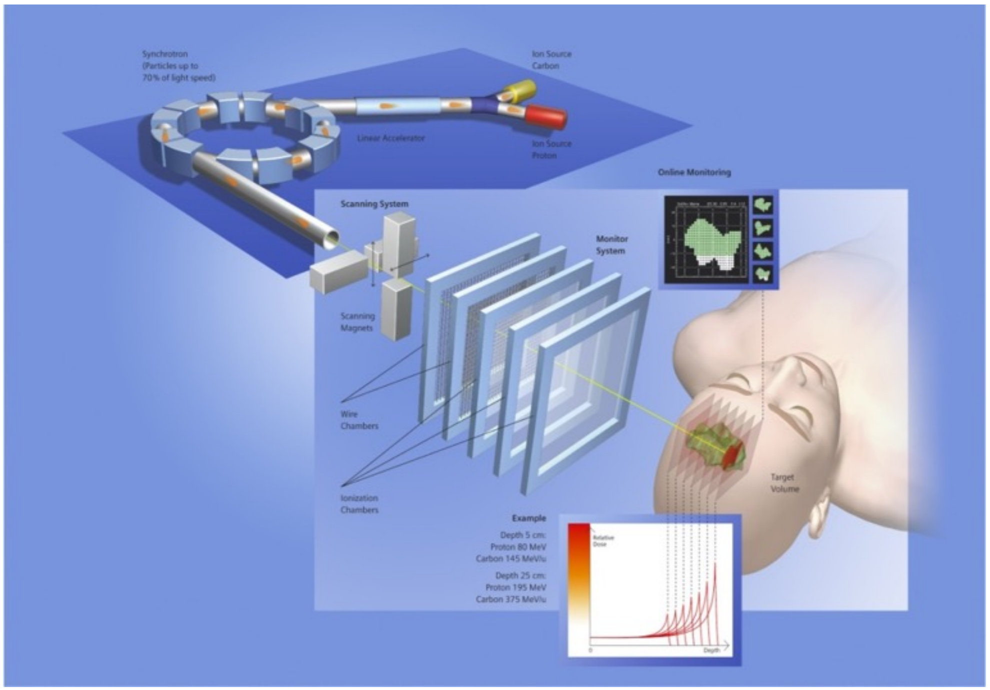
Horizontal Fixed Beam

p c

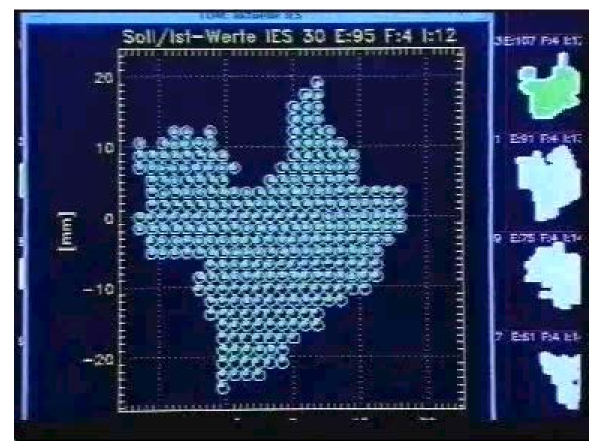
Protons &
Carbon Ions

Non-clinical Research

Irradiation concept



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

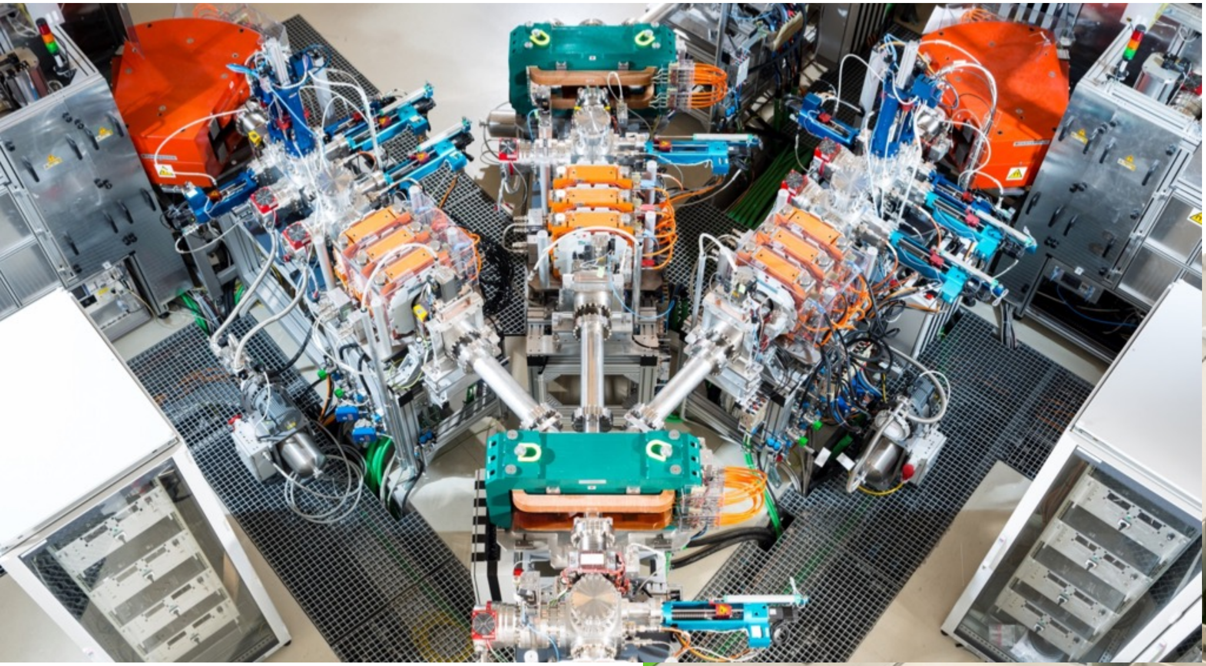


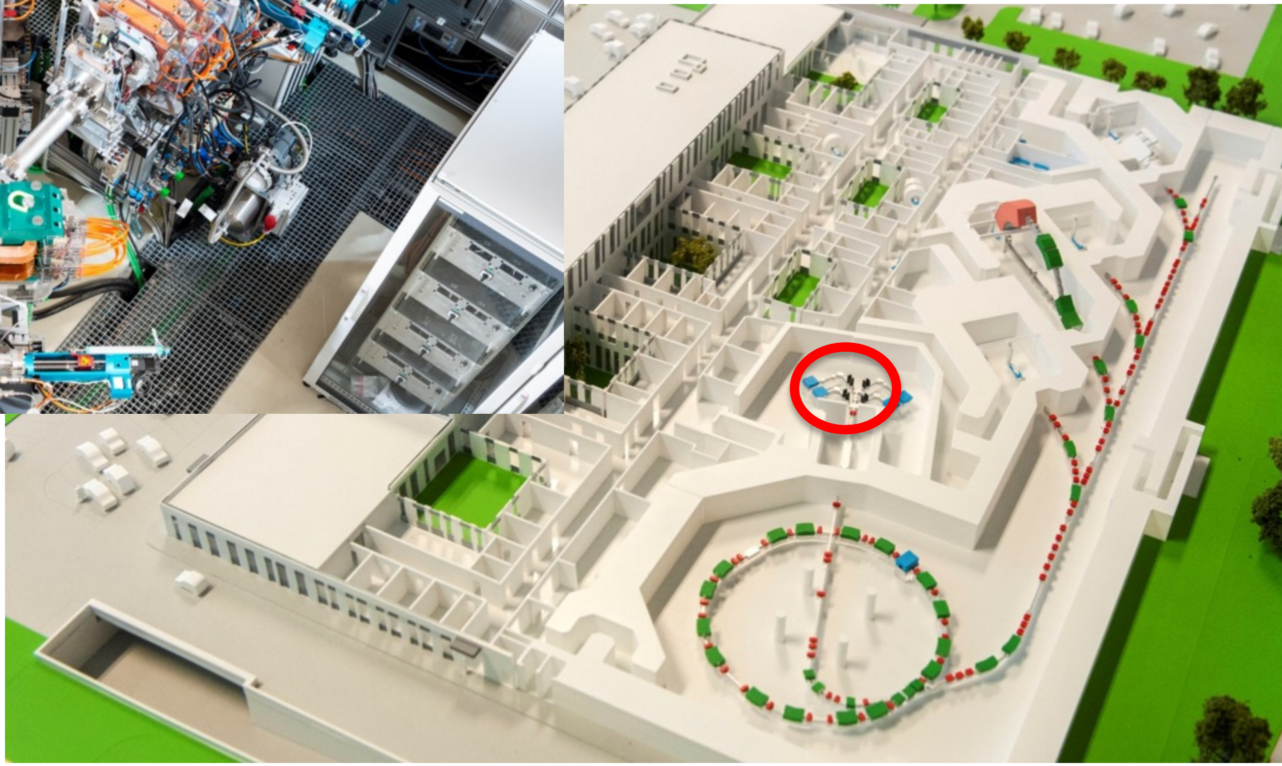
Courtesy of GSI

- no patient specific passive devices!

Source room

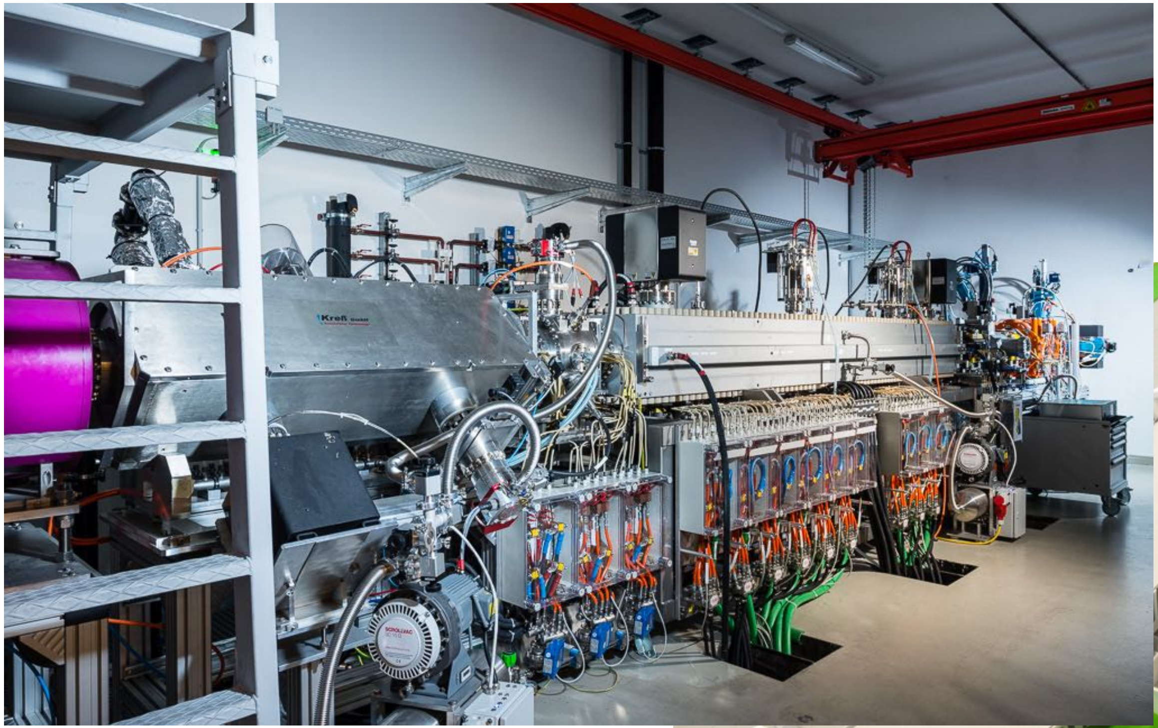
- Ion sources to produce protons or carbon ions
- Back-up source

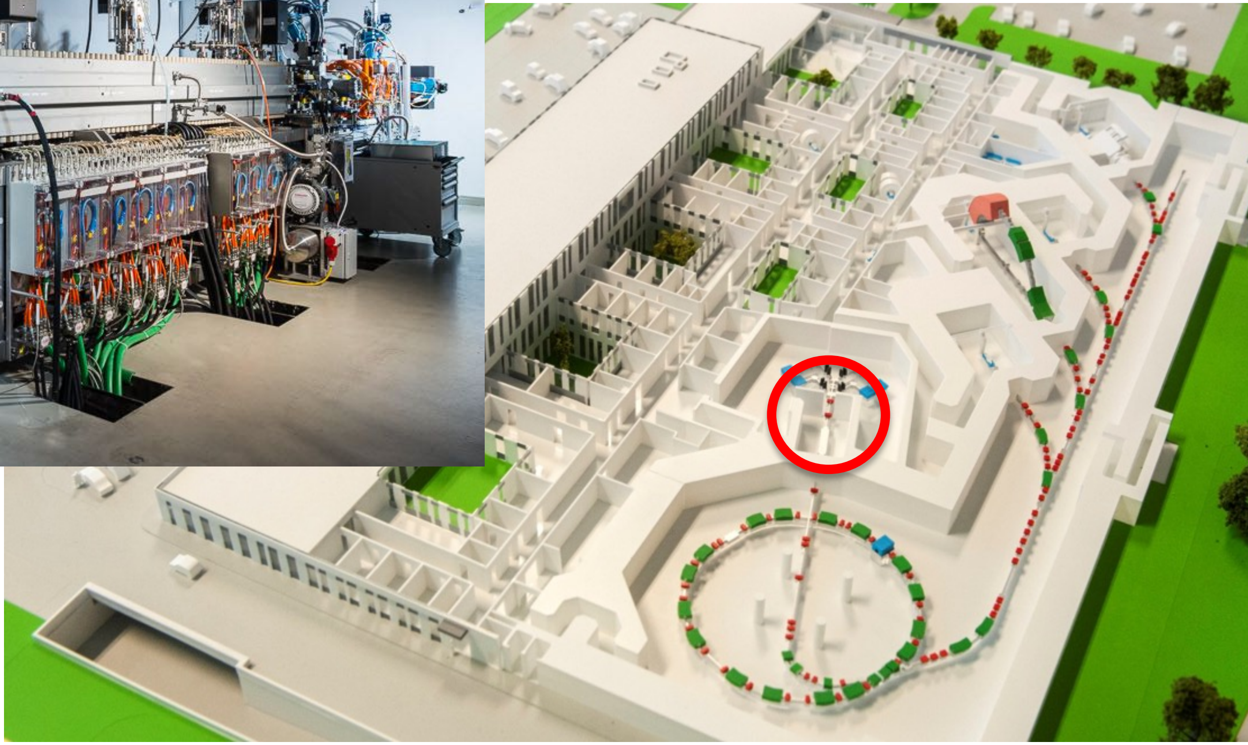




Linear accelerator

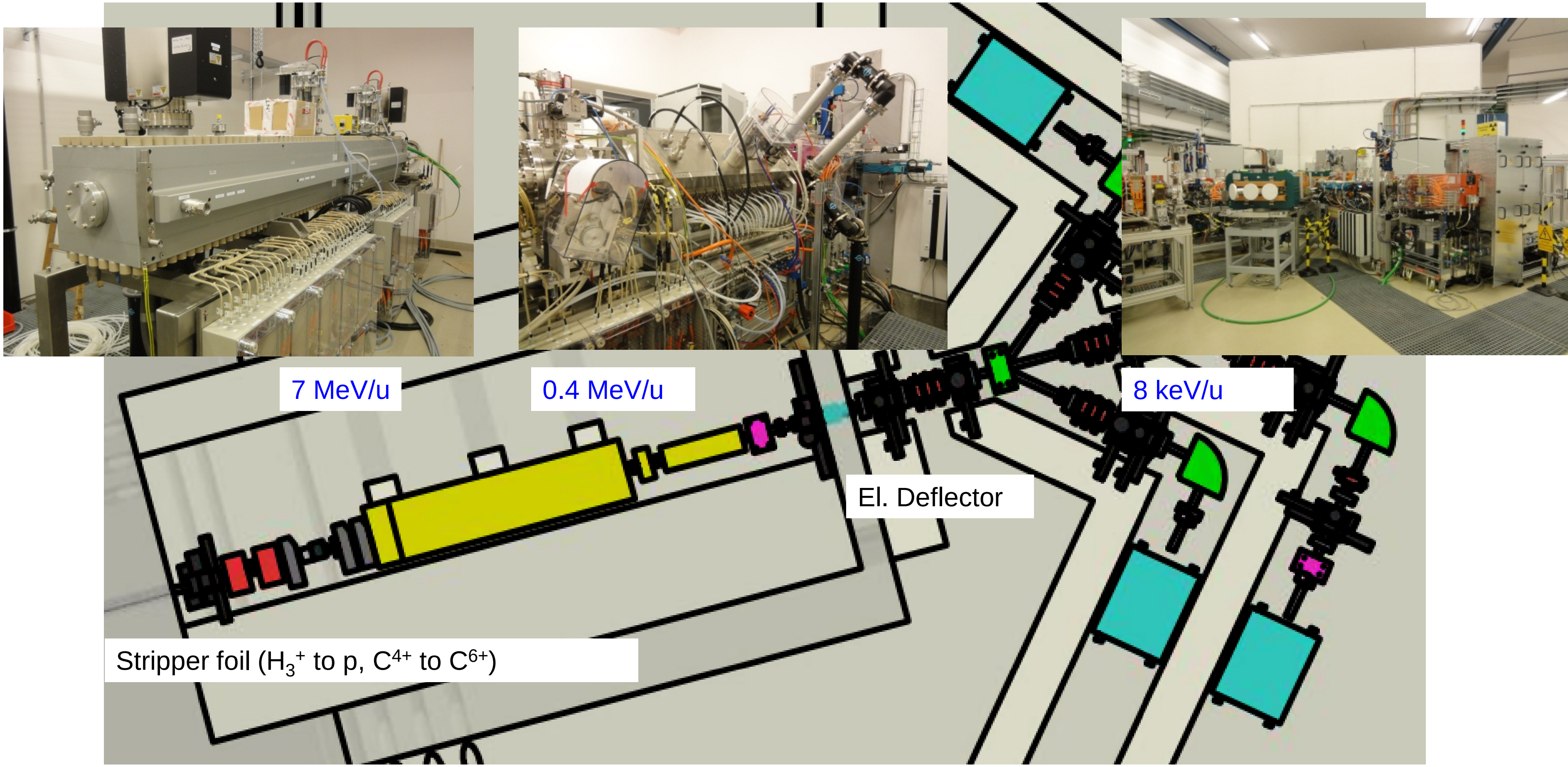
- Pre-acceleration and beam shaping to meet injection conditions of synchrotron





The Injector

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



Synchrotron

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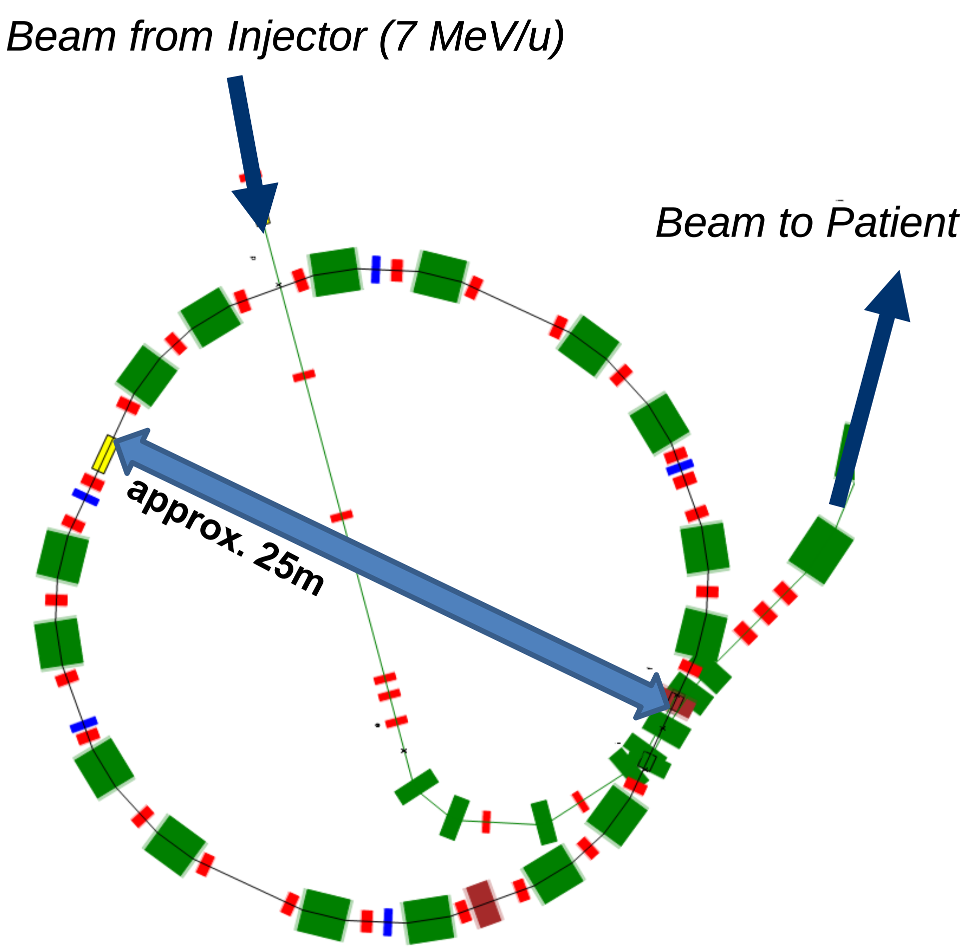
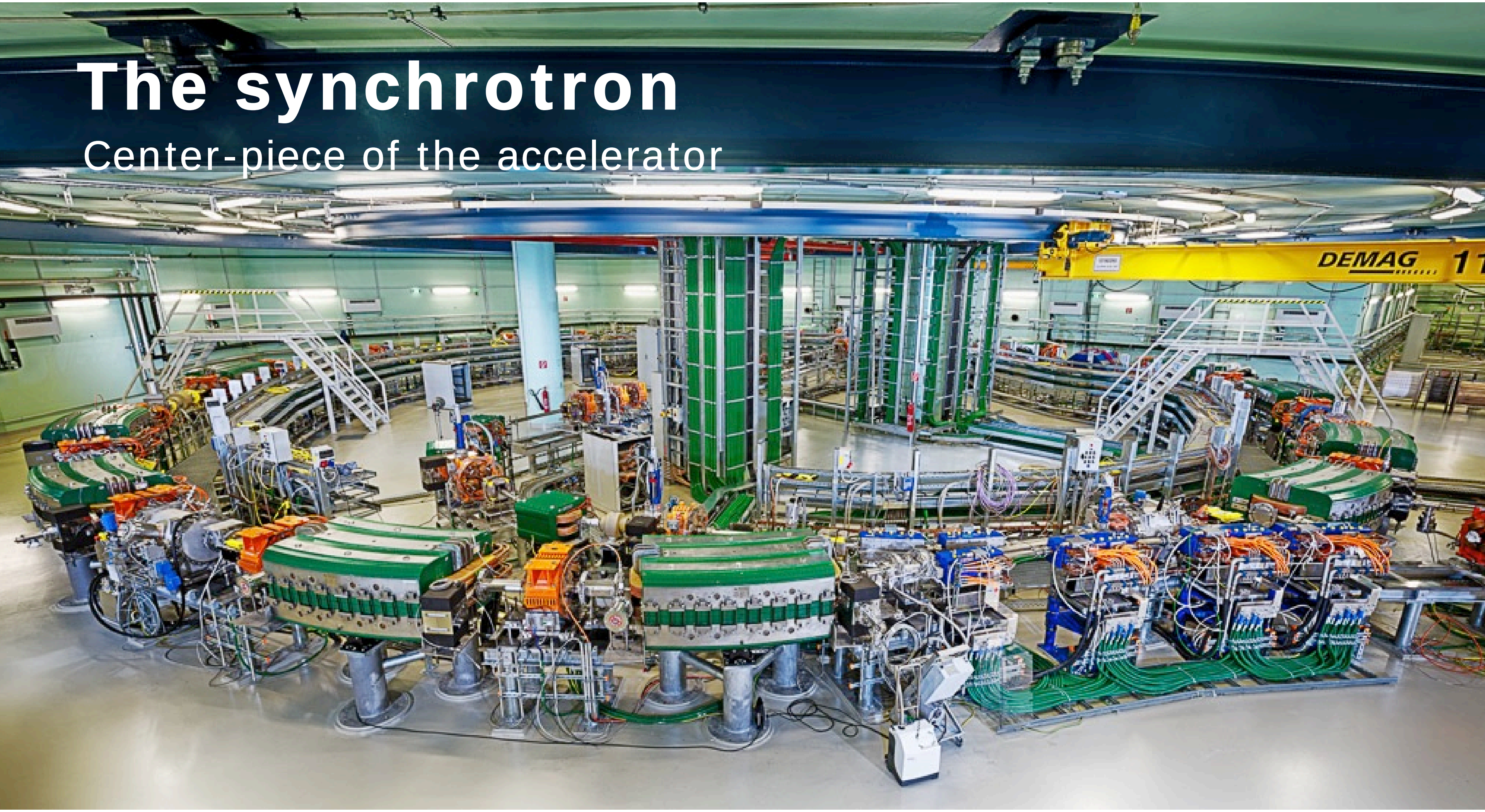


- Acceleration of beams to desired extraction energy
- Active energy selection:
  - 255 selectable energy steps (steps of 1 – 2 mm)
  - p: 60 – 250 MeV (NCR: 800 MeV)
  - C: 120 – 400 MeV/u
- Ramp speed: 0.5 s to highest energy
- Extraction time: 1 – 10 s

The synchrotron

Center-piece of the accelerator



Synchrotron

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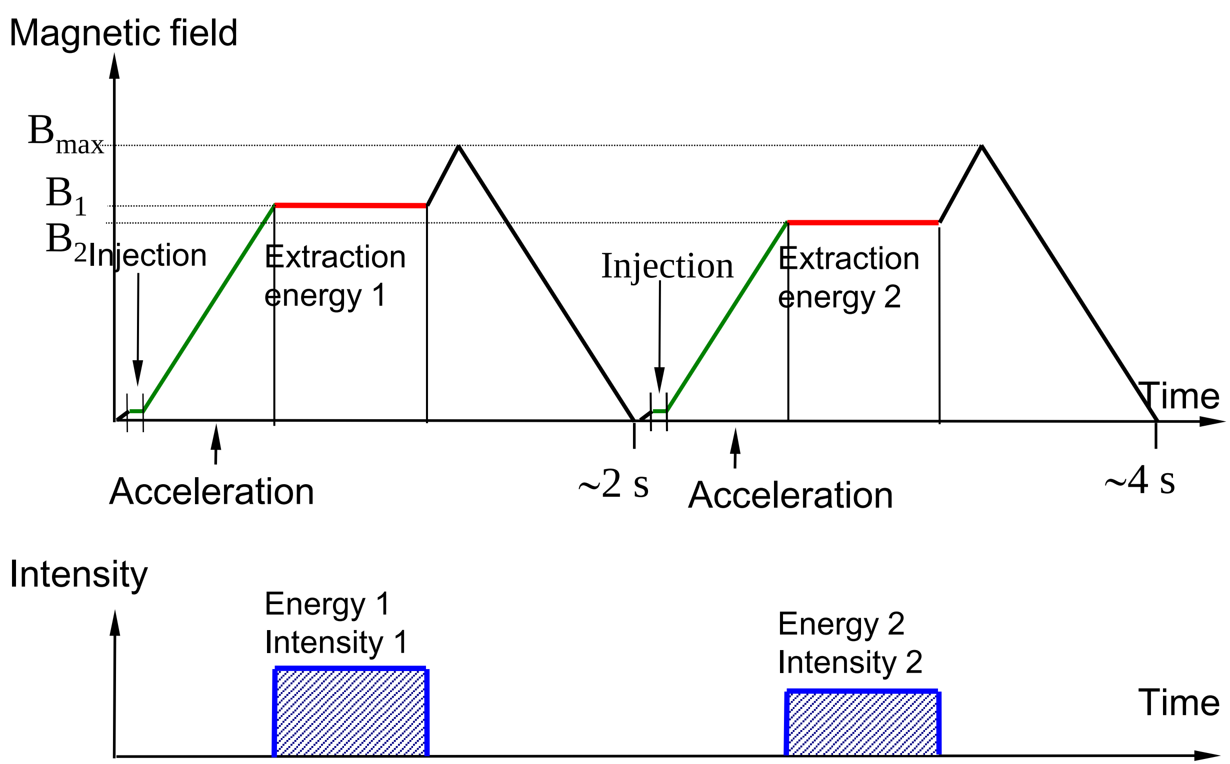
Typical cycle for a synchrotron for medical use with slow extraction.



- Beam structure: pulsed, energy and intensity variable

Synchrotron hall

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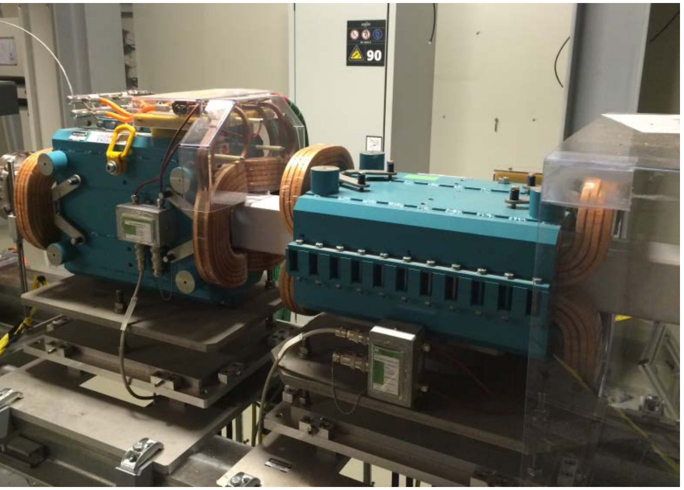
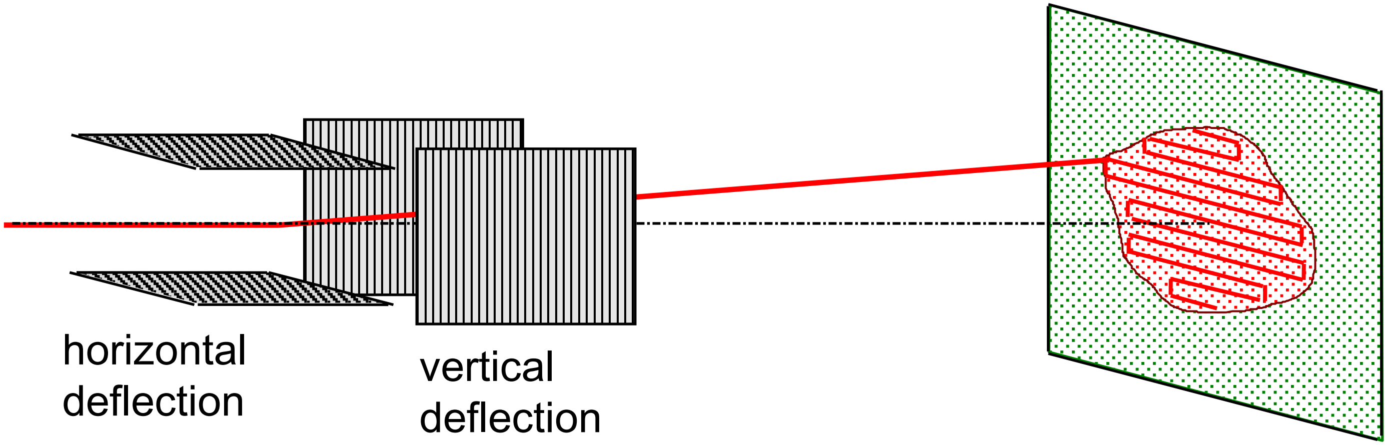
Extraction line

guiding the beam
into the 4 irradiation rooms

Scanning System



- 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

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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 cm^2 (IR1-3), 12x20 cm^2 (IR4)

Beam delivery precision

- < 0.5 mm

100.000 different beam combinations...

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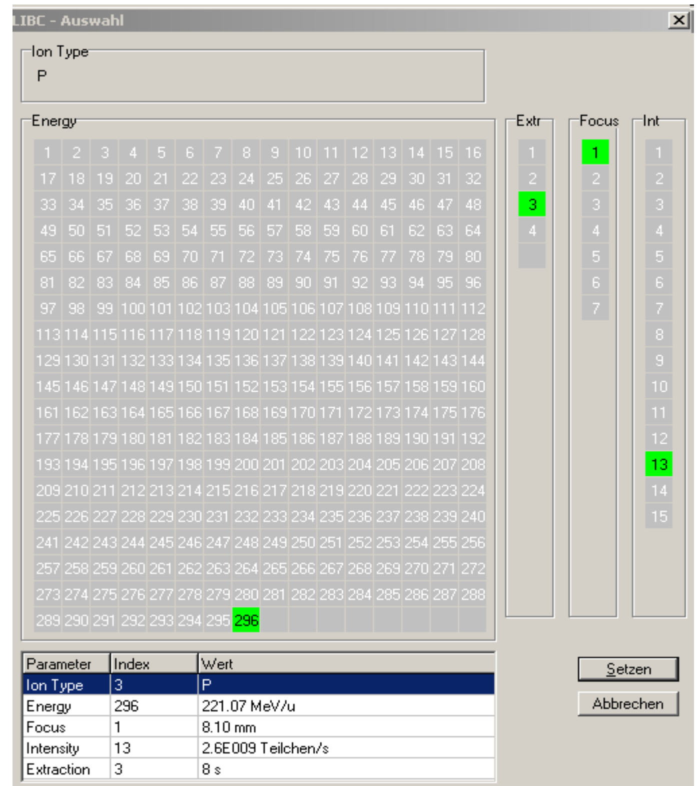
Accelerator is able to generate:

- **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

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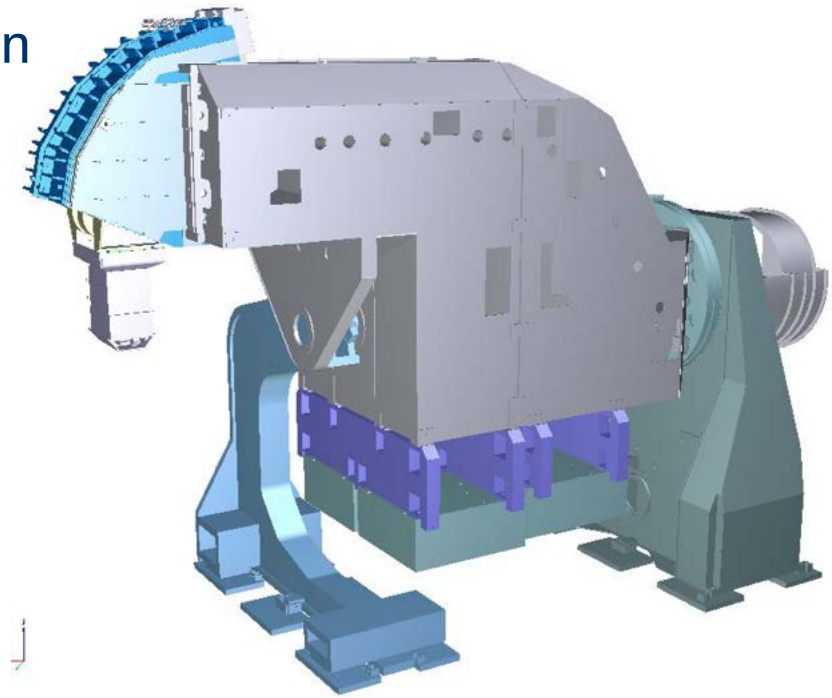
The proton gantry

- 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

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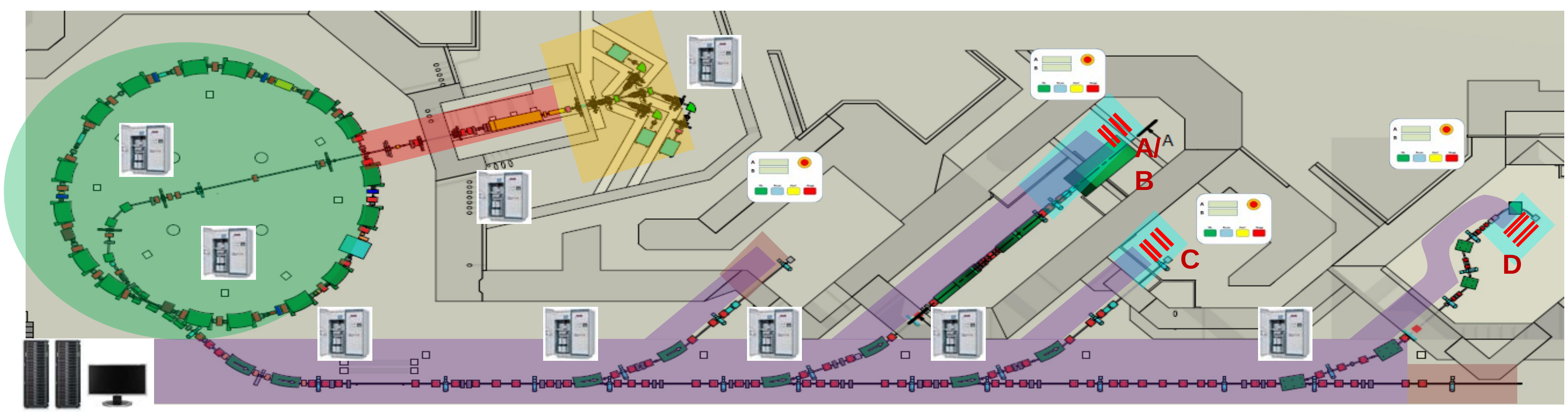
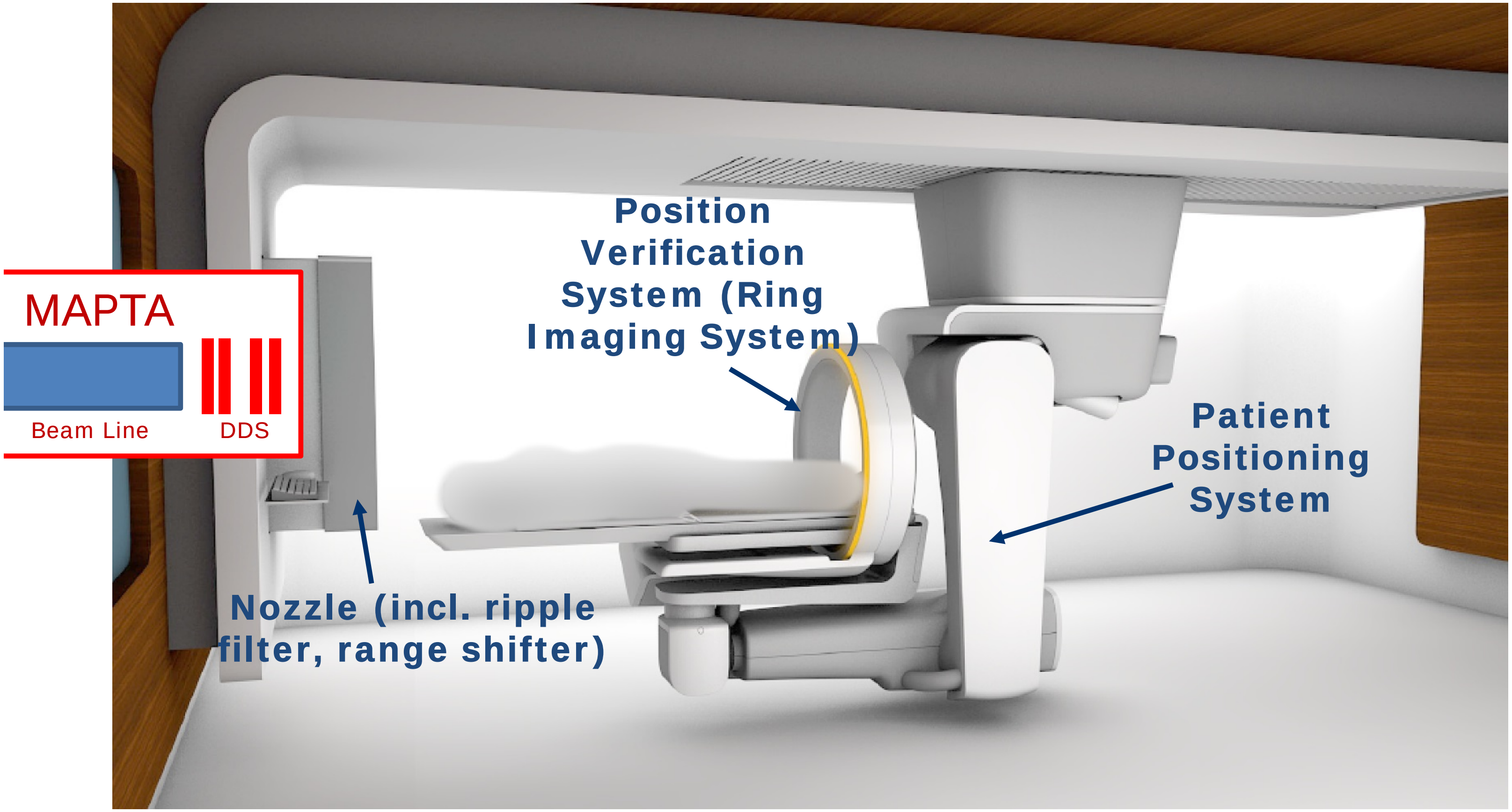
CE labelled medical product

- 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
- A / B — Clinical Beamlines IR2: horizontal 1 (A) and vertical (B)
- C — Clinical Beamline IR3: horizontal 2 (C)
- D — Clinical Beamline IR4: Gantry Beamline (D)
- MAPTA Treatment Control Panel (Local Control Rooms 1 to 4)



CE according to Medical Device Directive (MDD)

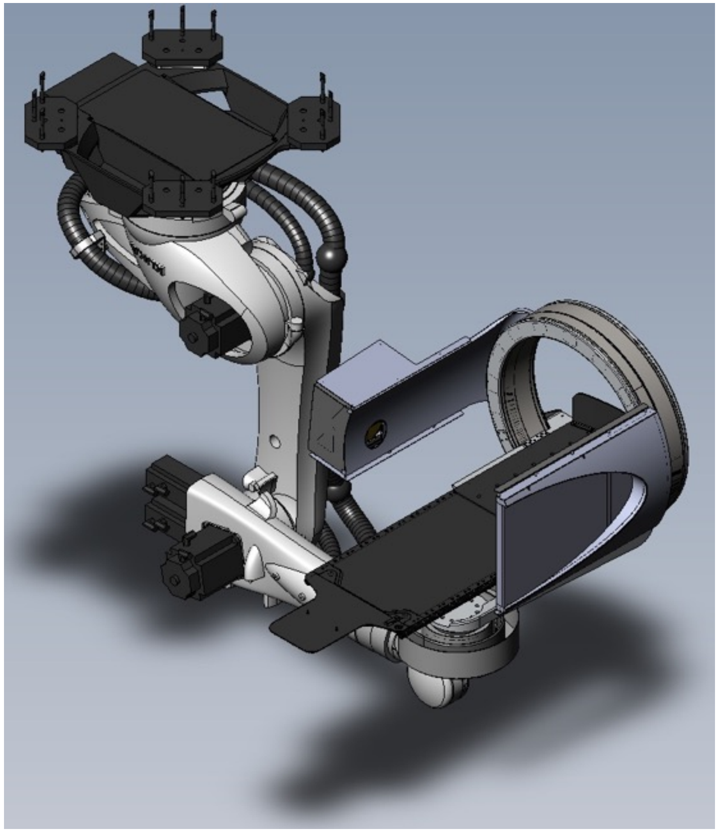
Irradiation room



- 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



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Patient position verification system

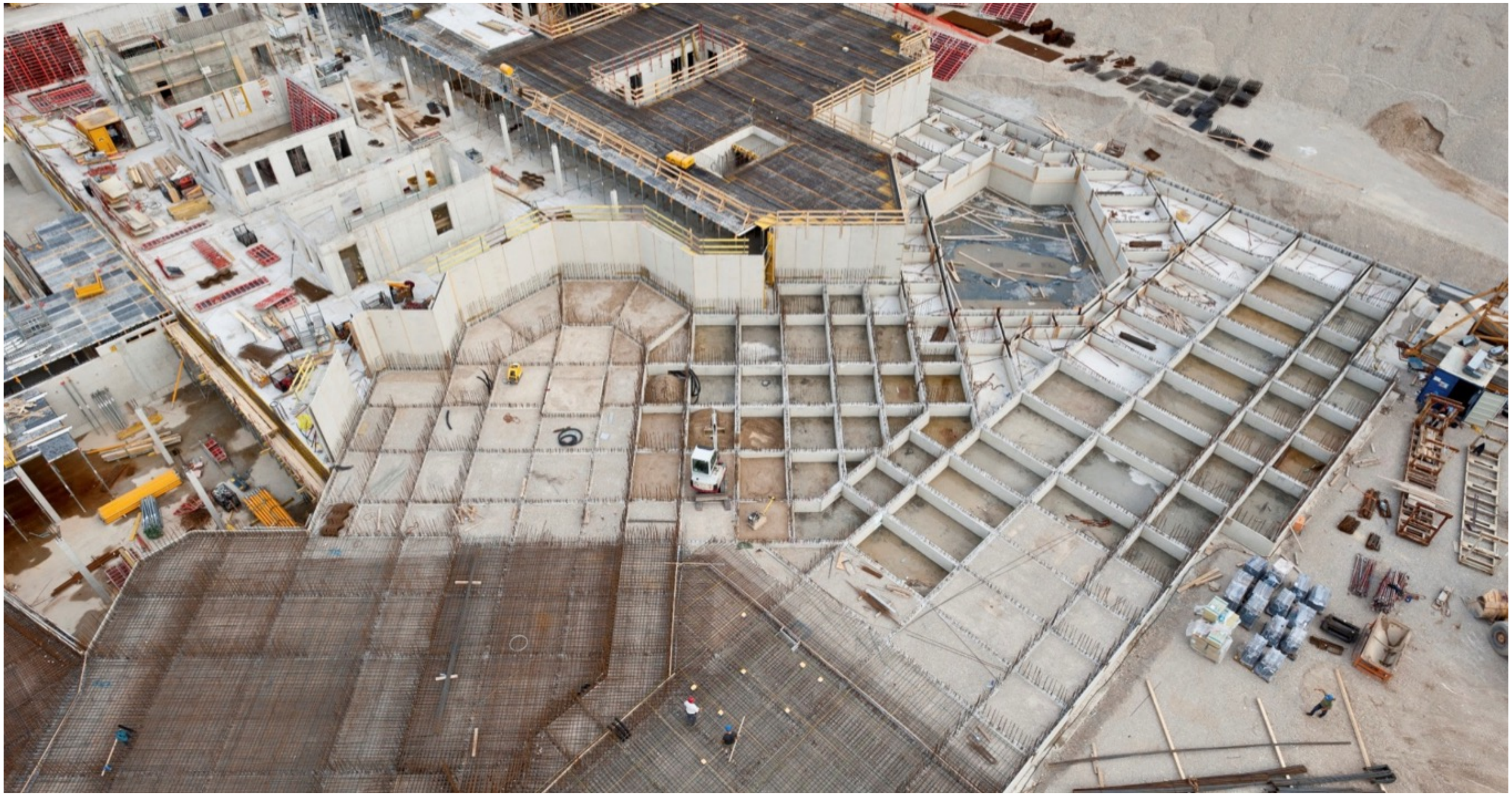
- Flat panel and X-ray tube rotatable around the ring, couchmounted
- fast flat panel detector (30 Hz framerate)
- single source dual energy X-ray (60, 120 kV)
- large clearance (78 cm ring)
- 2D, 3D imaging
- cone beam CT

Patient positioning and verification system

MedAustron: project timeline and status

Construction
2011- 2012 (18 months)

Construction 2011- 2012 (18 months)



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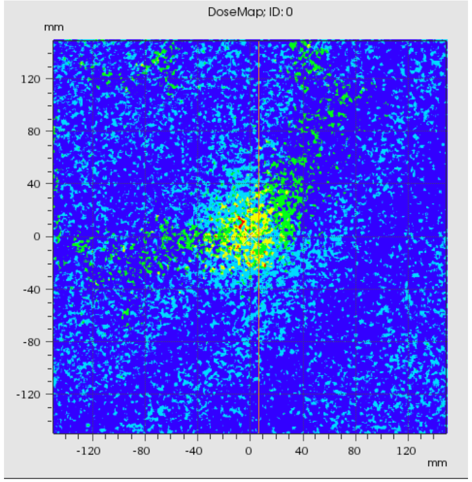
Oct 2012: Moving in

Accelerator installation 2013 - 2014



First beam in IR3 in Oct. 2014

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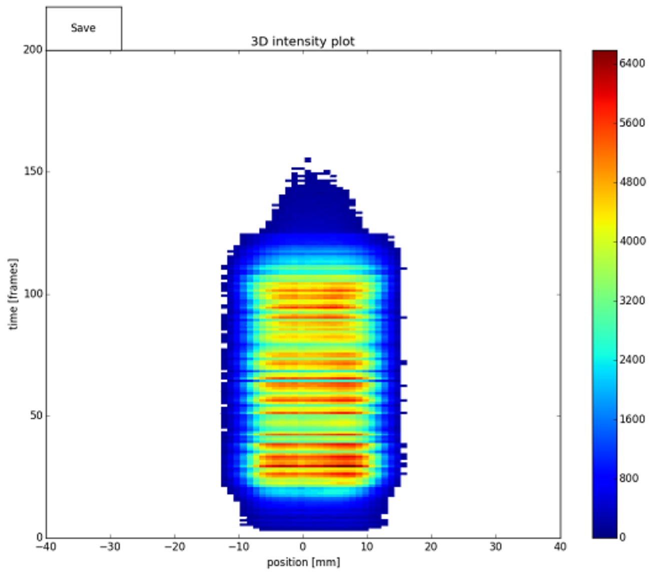
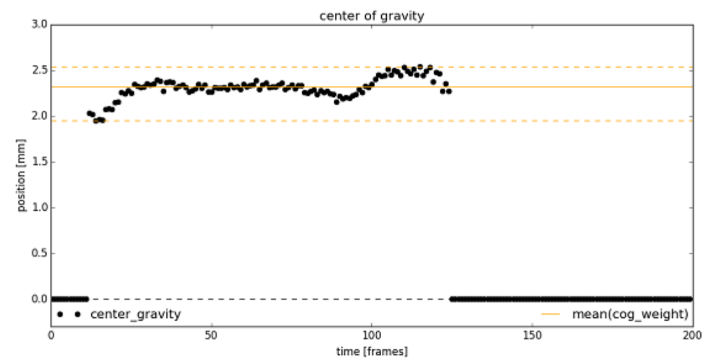
Accelerator commissioning 2015

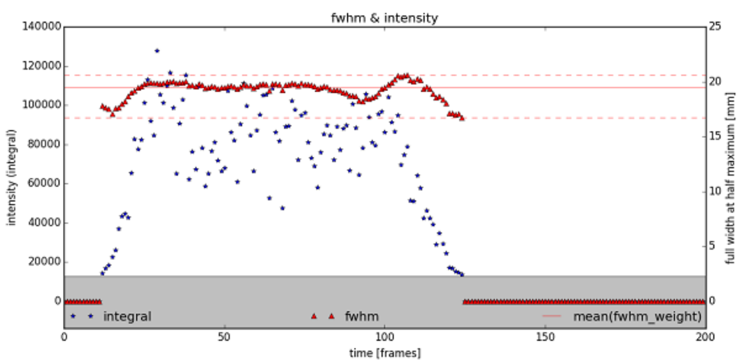
- work in progress
- intensity, beam position and FWHM beam size over extracted spill measured in HEBT



CC	004440441009026C
VACC	na
BS	2015100810082200-6
noiseth.	2.0 %
analimit	10.0 %
IID	0
SID	0

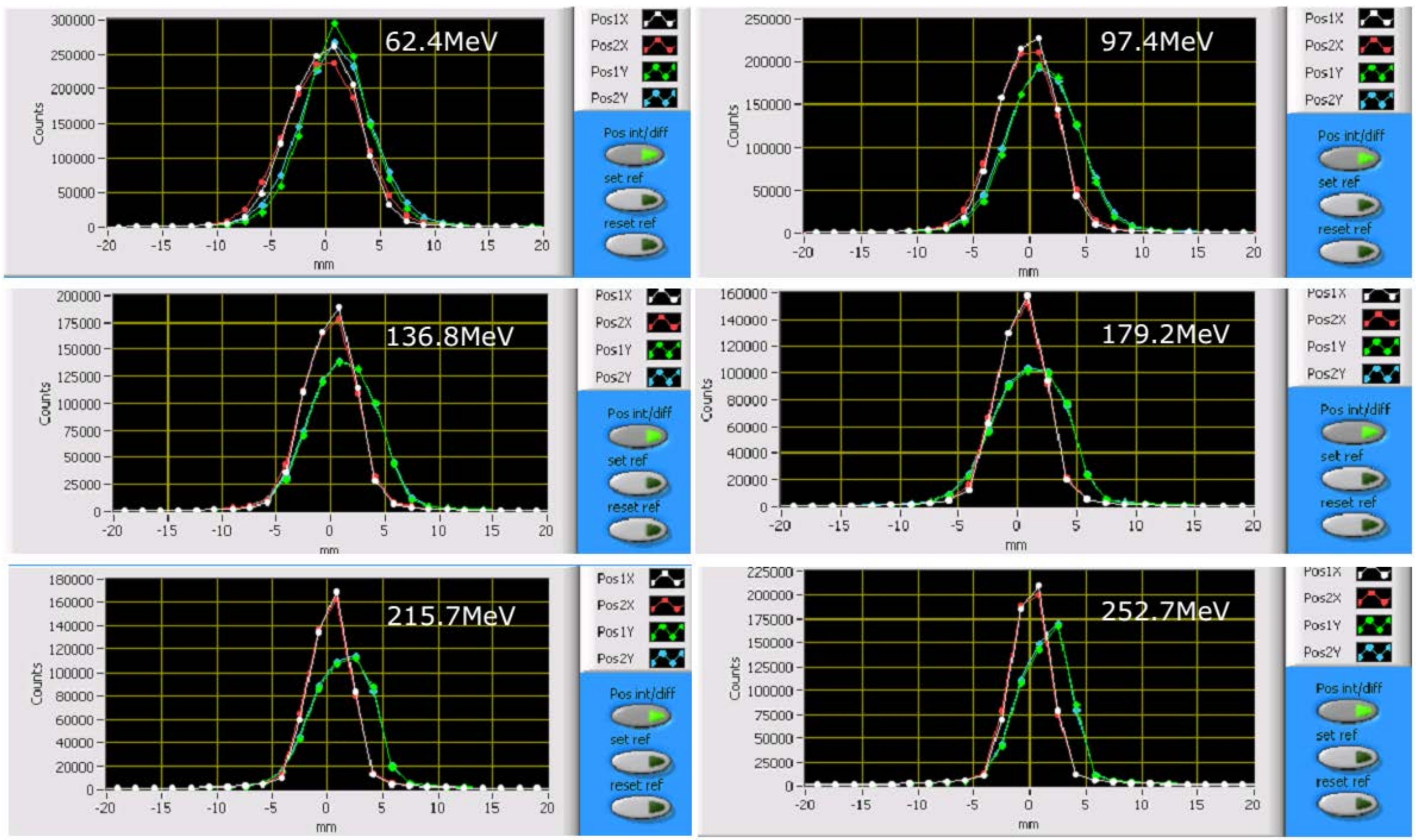
exp.time	19.999999552965164 ms
framerate	25 f/s
trigger	StartExtraction
date	2015-10-08 08:12:45.629585
intensity	8e6 arb.u.
CoGw	2.3 ± 0.1 mm [2.0, 2.5]
FWHM	19.5 ± 0.8 mm [16.7, 20.6]





Accelerator commissioning 2015

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



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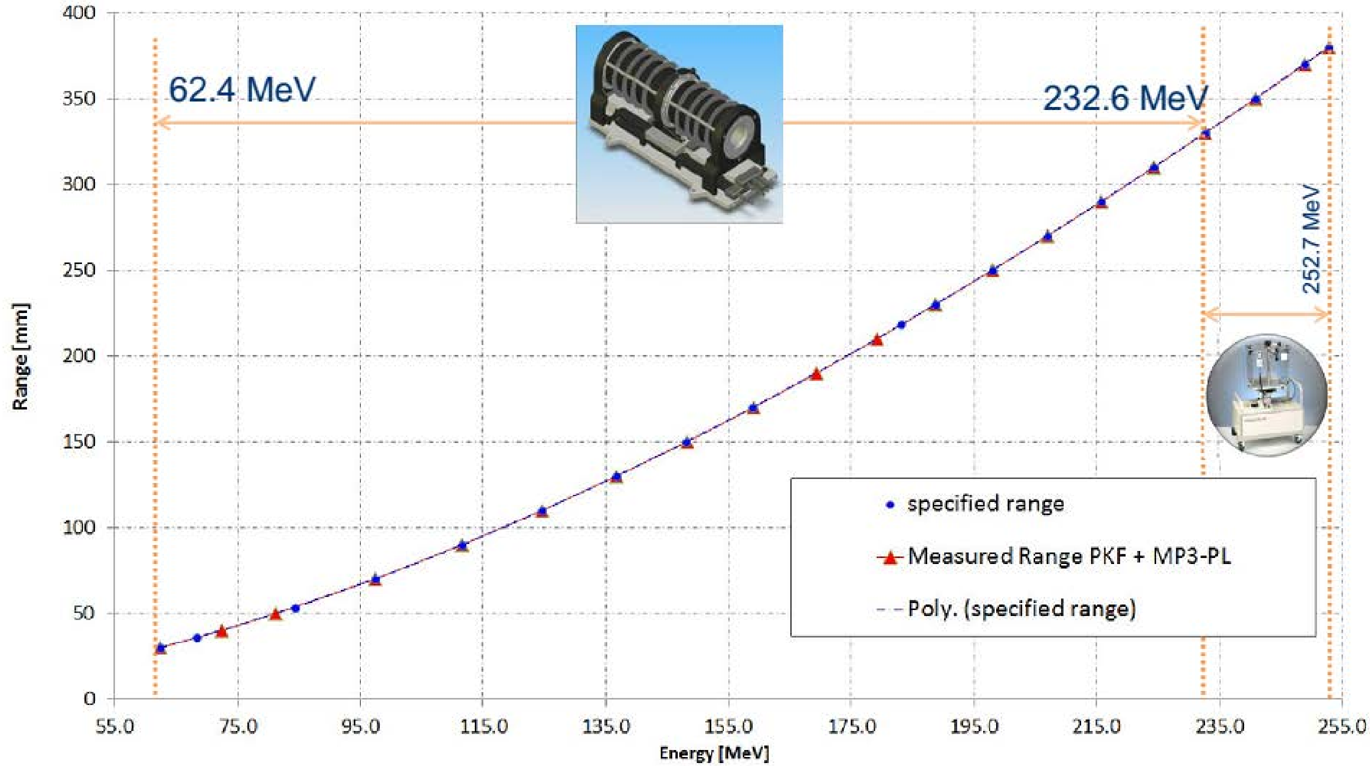
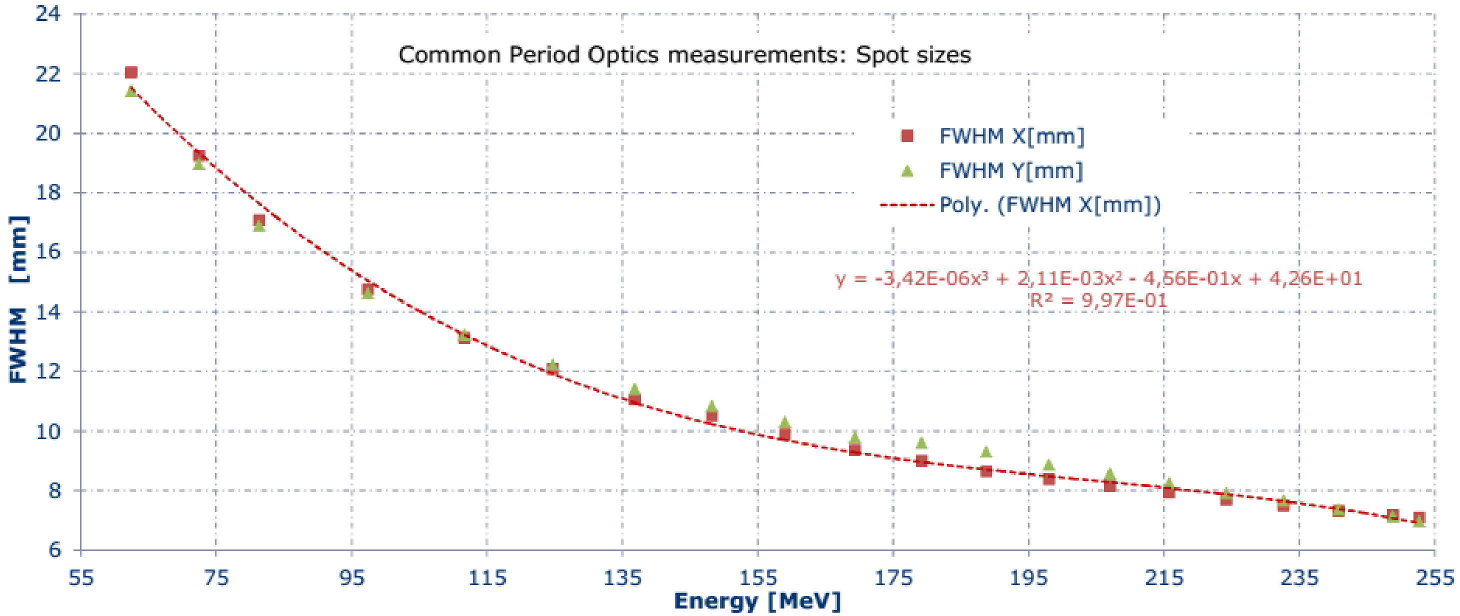
Penetration depth



- Particle energy successfully adjusted within a single iteration round.

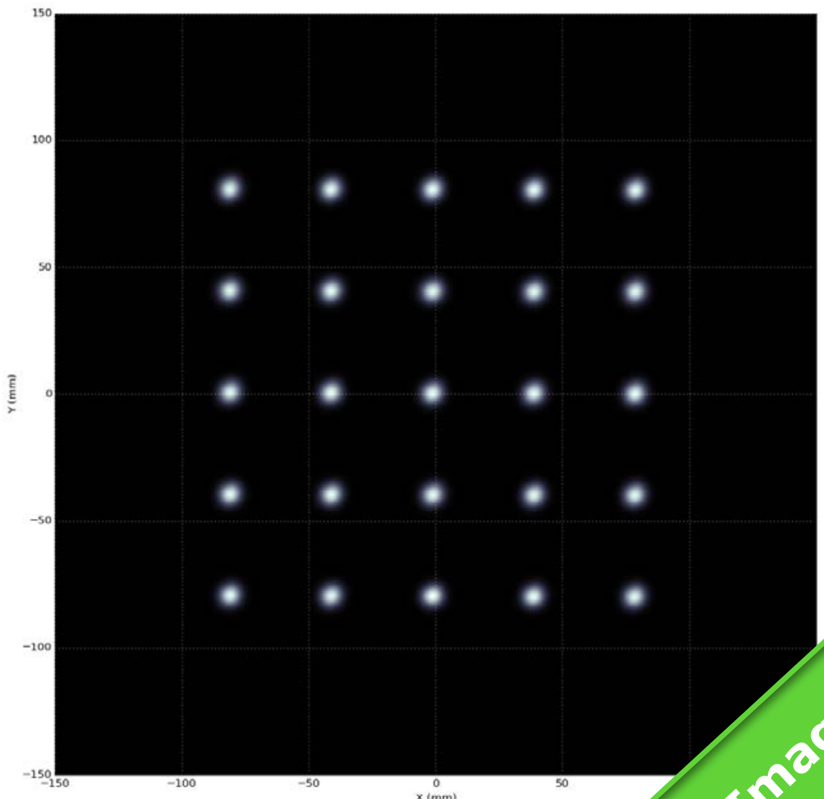
Beam size



- measured at isocenter
- beam size and symmetry adjusted within a single iteration round.

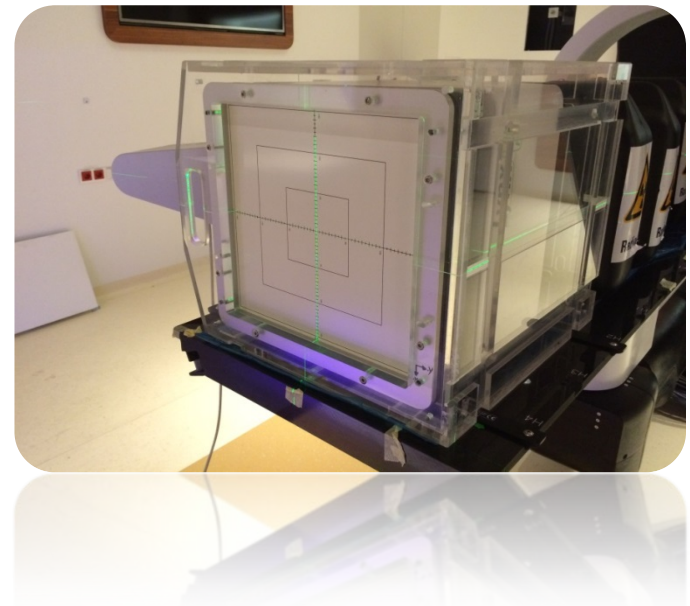
Recent commissioning results

250 MeV Scanned Proton



FWHM x: 7.0 mm
FWHM y: 7.0 mm

Image



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Recent commissioning results

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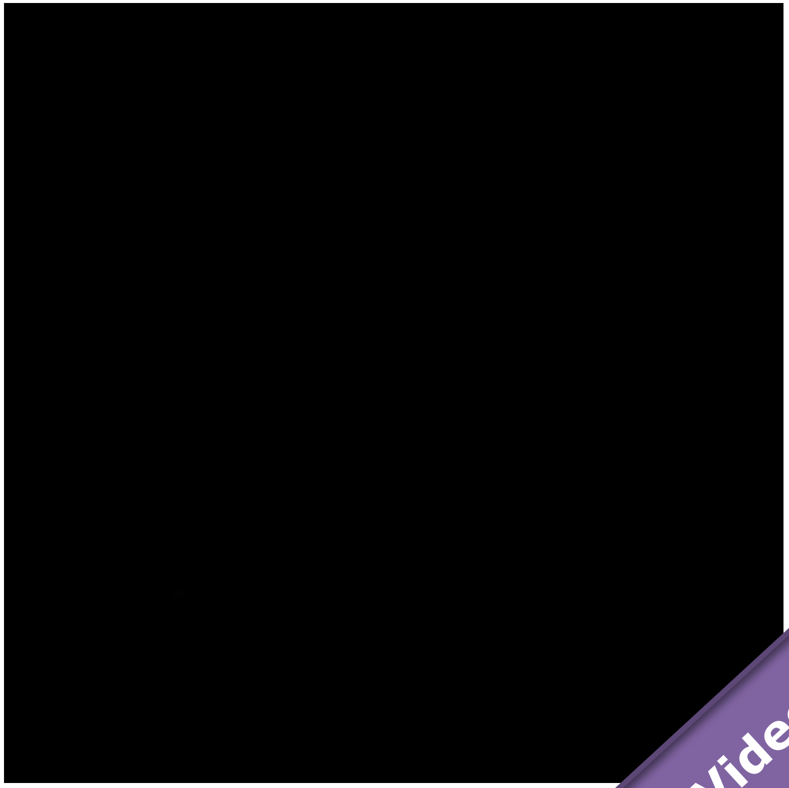
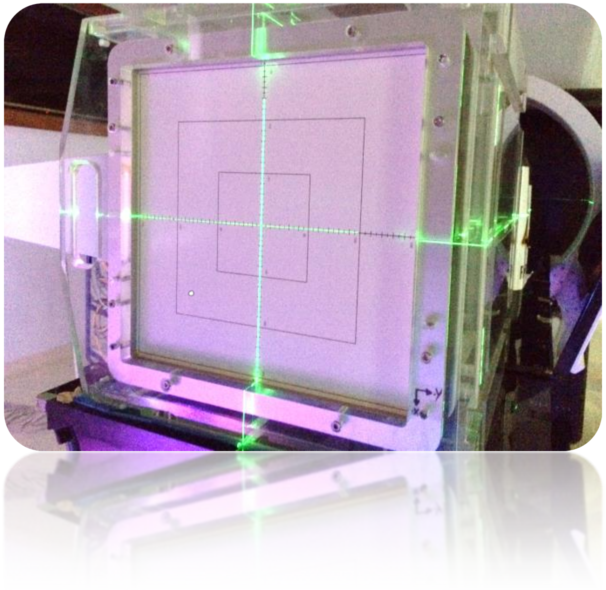


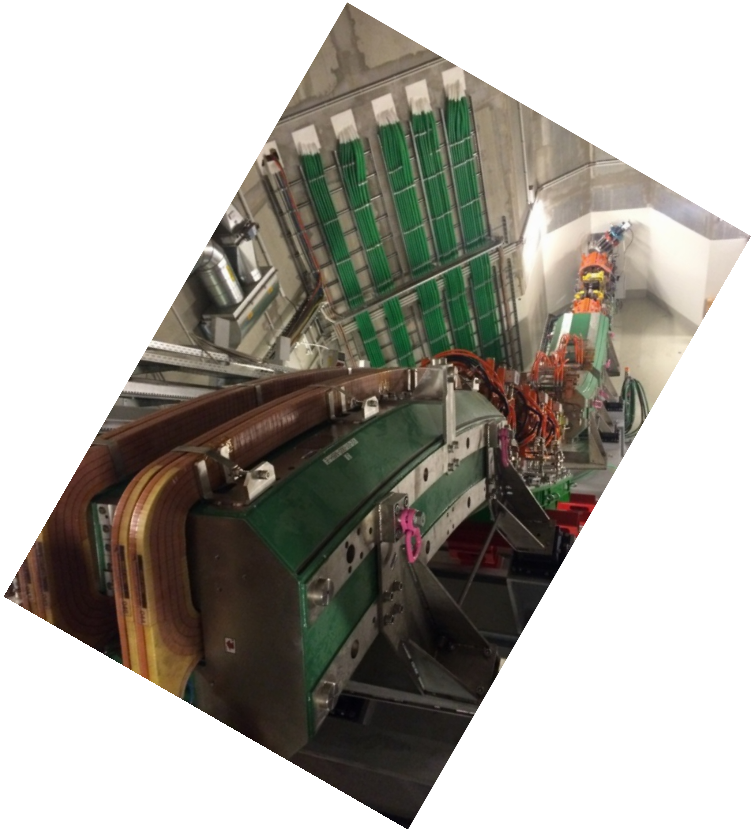
FWHM x: 7.0 mm
FWHM y: 7.0 mm

Video



Installation of vertical beam line

- Vertical beam line installed in Q4 2015
- Beam commissioning in 2017



Remaining steps towards 1st 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

1st 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

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Thank you for your attention!