

MedAustron: From Concept to the Future...

Claus Schmitzer

WHO we are

A centre for ion therapy for cancer treatment and for research.

Our facility is unique in Austria and worldwide, there are only a few comparable centres.

Carbon Ion Centers Worldwide: 11

(in operation by April 2018)

4

Europe

HIT Heidelberg
MIT Marburg
CNAO Pavia
MedAustron

7

Asia



Particle Therapy Centers in Europe: 21

(in operation by April 2018)

- Protons
- Protons &
Carbon Ions



MedAustron in Austria

Wiener Neustadt



MedAustron Center



MedAustron in Austria

OWNERSHIP STRUCTURE



MedAustron Center



MedAustron in Austria

OWNERSHIP STRUCTURE



Our main task is the operation of the facility as an outpatient clinic.

Treatment of up to 1000 patients/year in full operation from Austria and foreign countries.

We focus on the further development of this treatment method and the technology behind.

Our facility is used for basic and translational research.

»EBG« stands for construction and operating company.

MedAustron in Austria

FINANCING STRUCTURE

Investment: 200 MEUR

Financing:

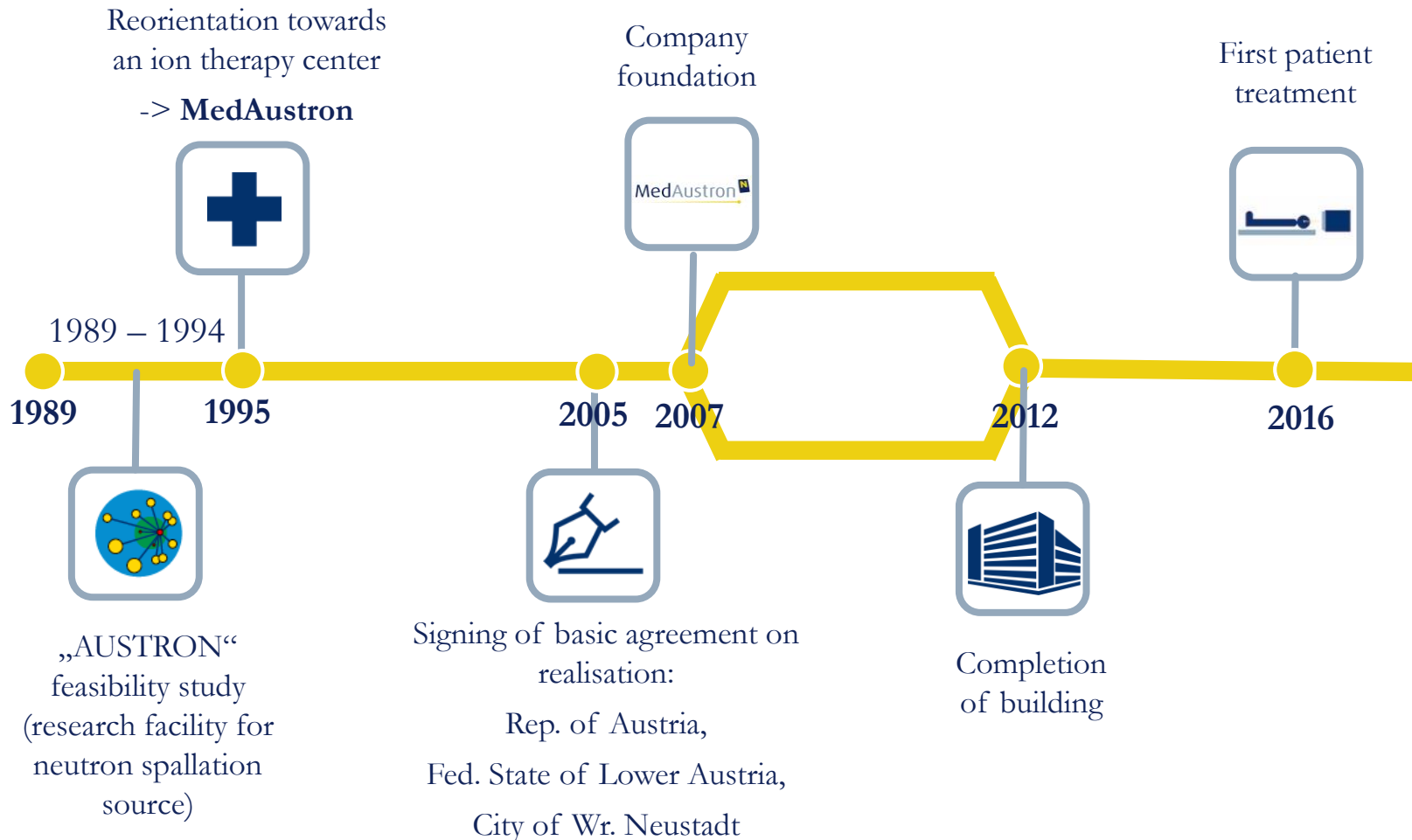
- State of Austria:
 - 41 MEUR (for research part)
- Federal state of Lower Austria:
 - 32 MEUR of equity capital
 - 3.7 MEUR (for research part)
 - 220 MEUR of liabilities
- City of Wiener Neustadt:
 - 1.9 MEUR (for research part)
 - 3.2 ha estate
- **Reimbursement** contract with health insurance system in Austria:
 - List of indications (sarcoma, adenoid-cystic carcinoma, pediatric tumors, meningioma,...)
- **Pricing** for domestic patients (depending on tumor type): 36.000 € to 50.000 € (VAT incl.)

MedAustron Center

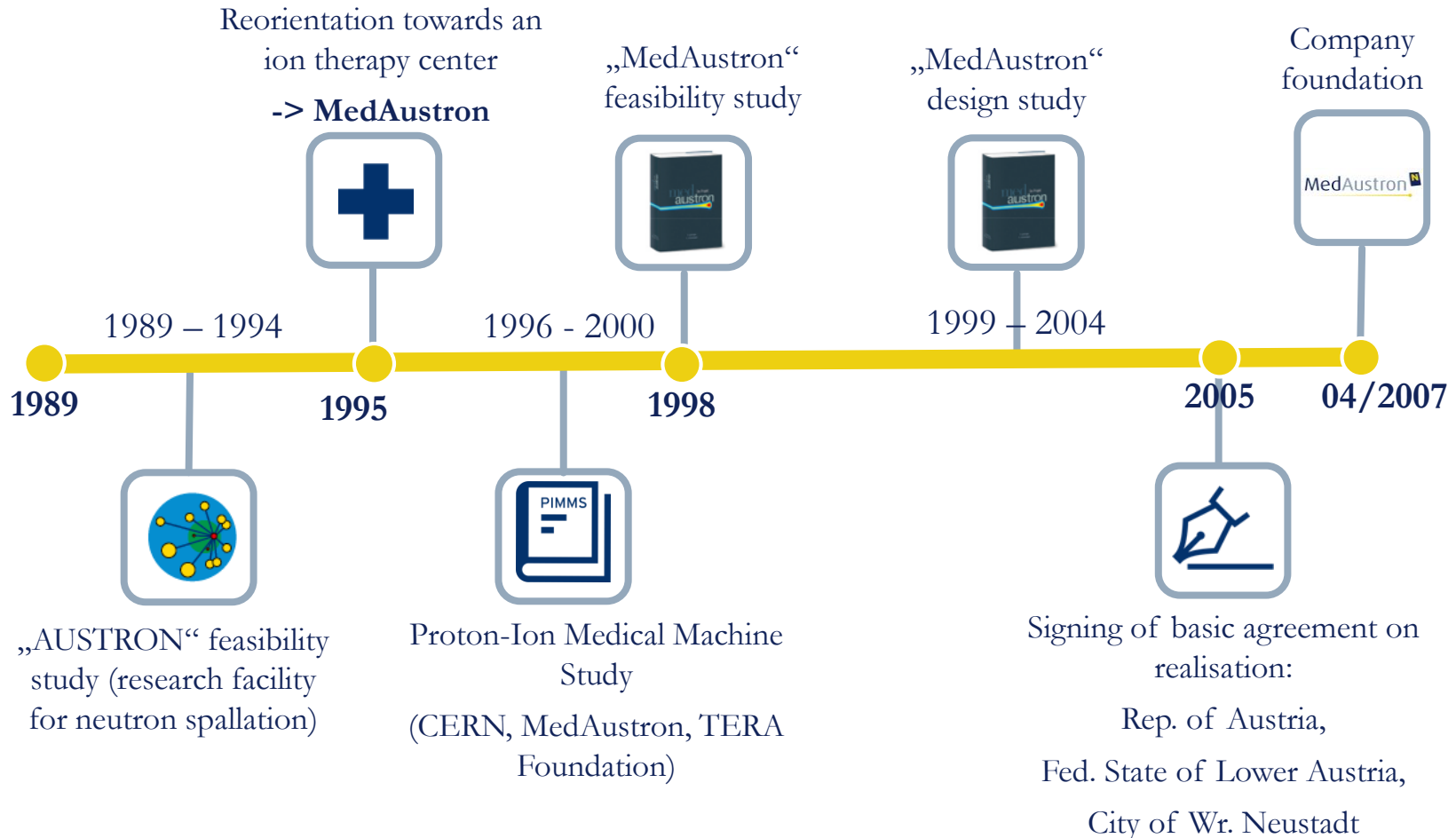


From concept to clinical operation

From first initiatives to first patient treatment - almost 30 years of history

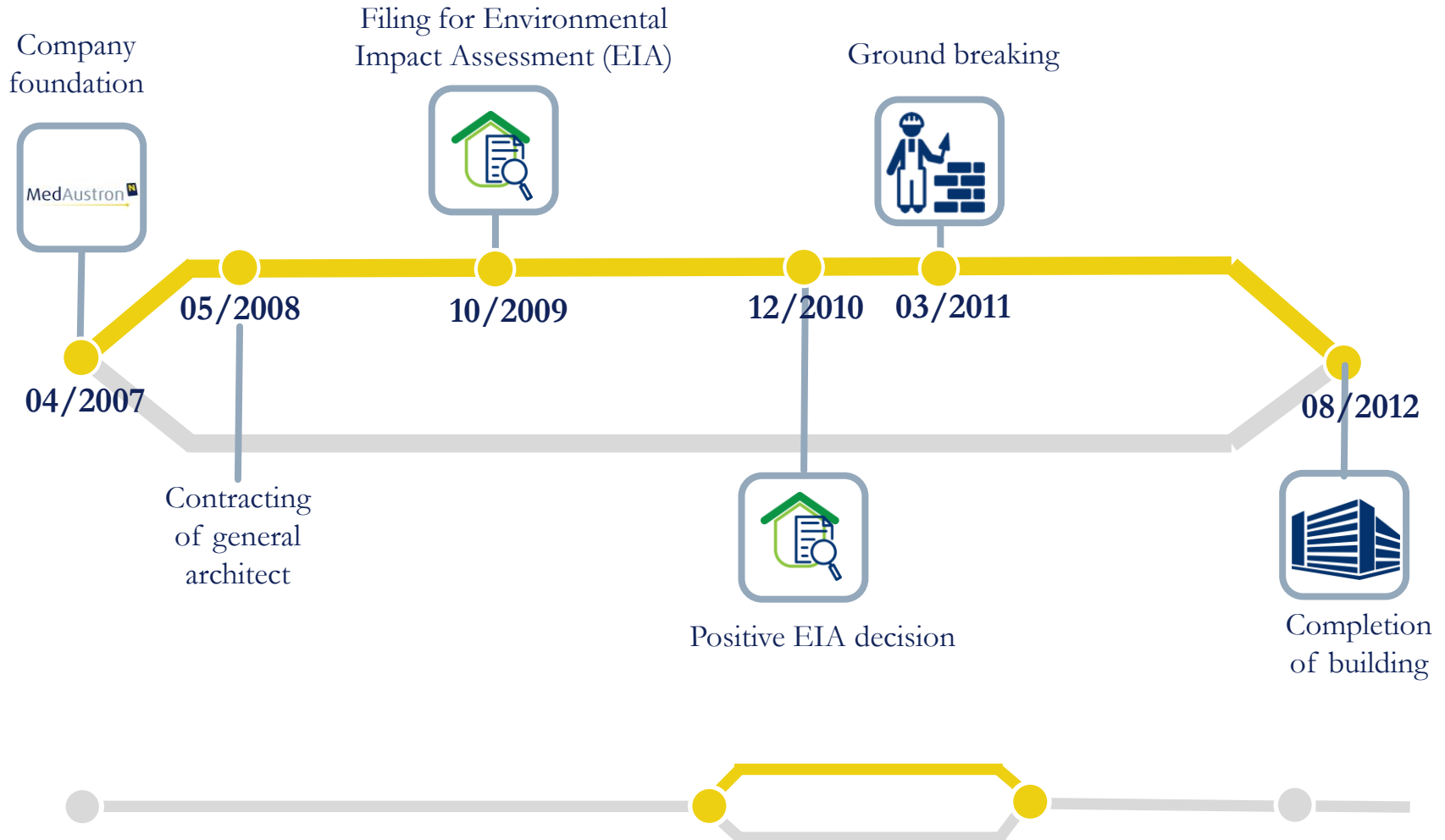


From concept to clinical operation



From concept to clinical operation

- Building branch



Building construction (09/2011)



Building construction (09/2011)

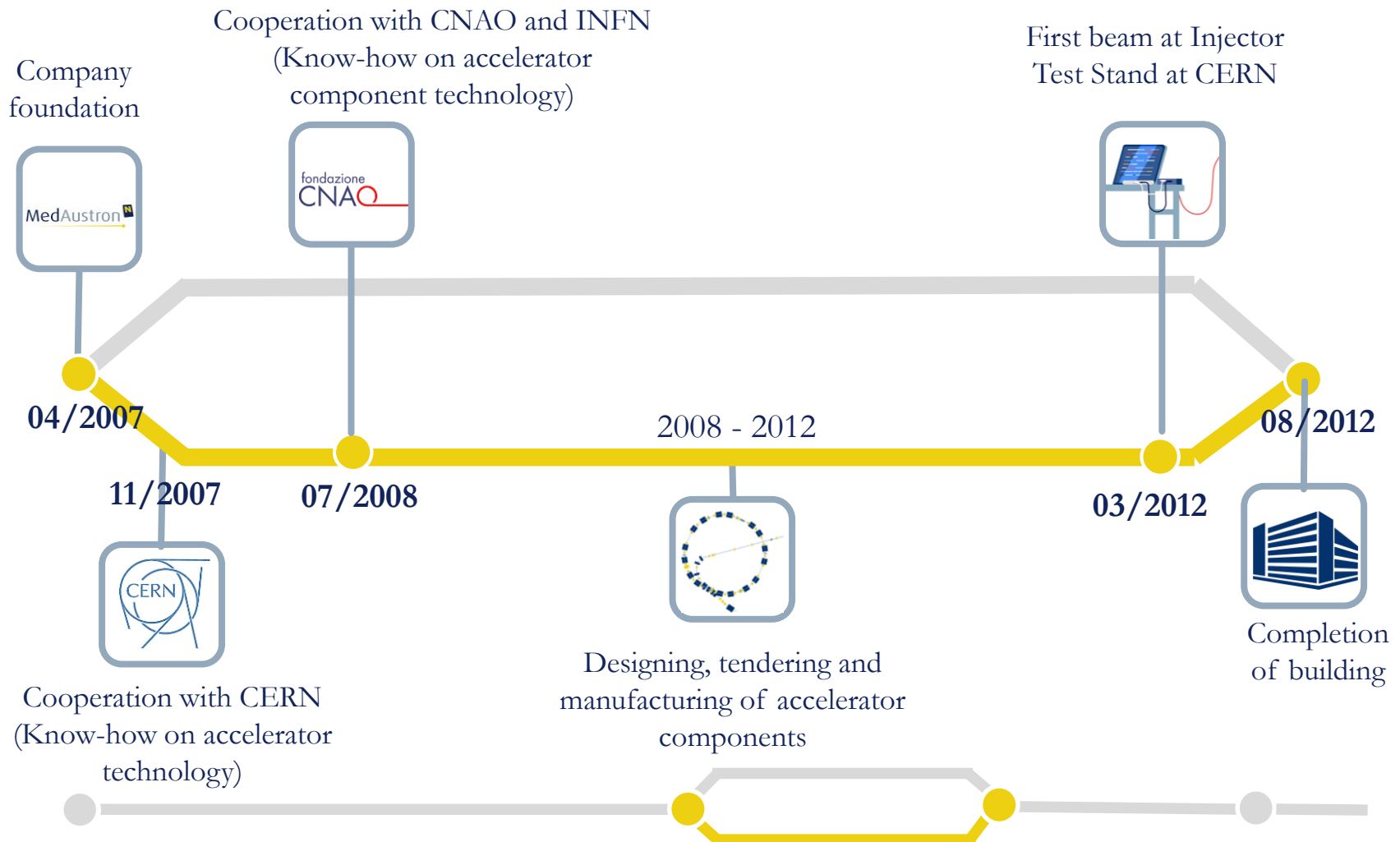


Completion of building (08/2012)



From concept to clinical operation

- High technology branch



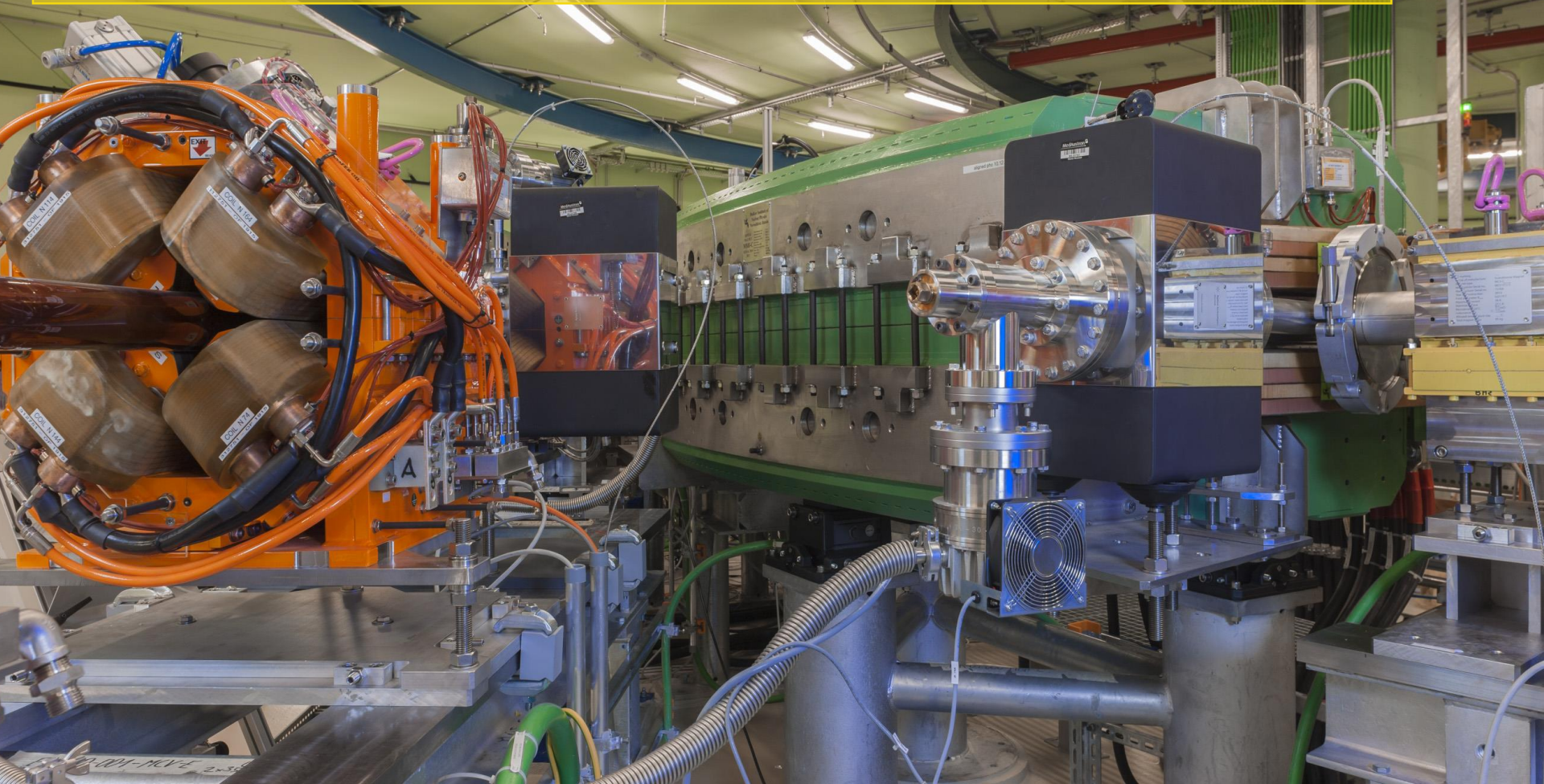


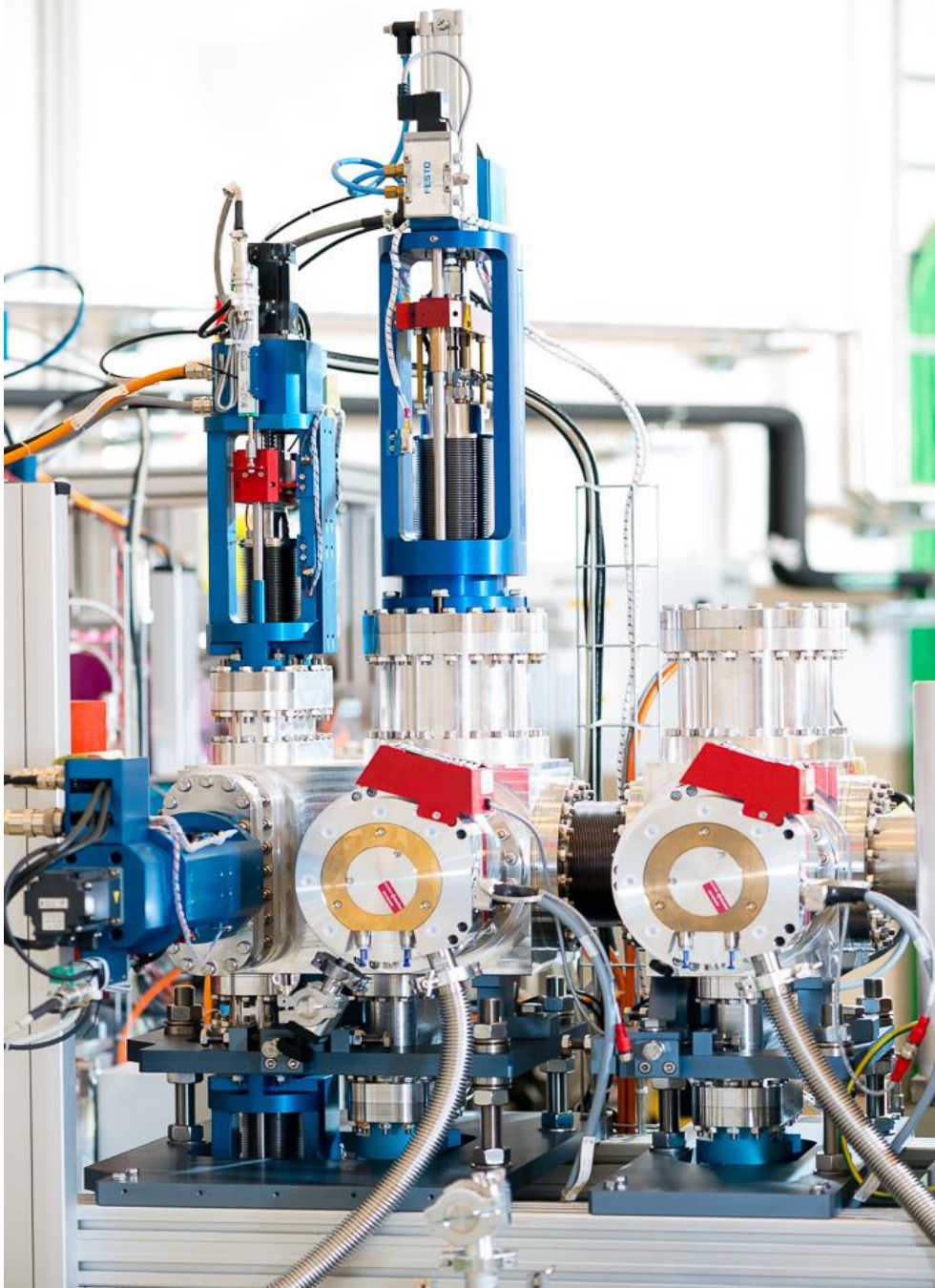
ION SOURCES

Origin of the particle beam

Dipole and Quadrupole Magnets

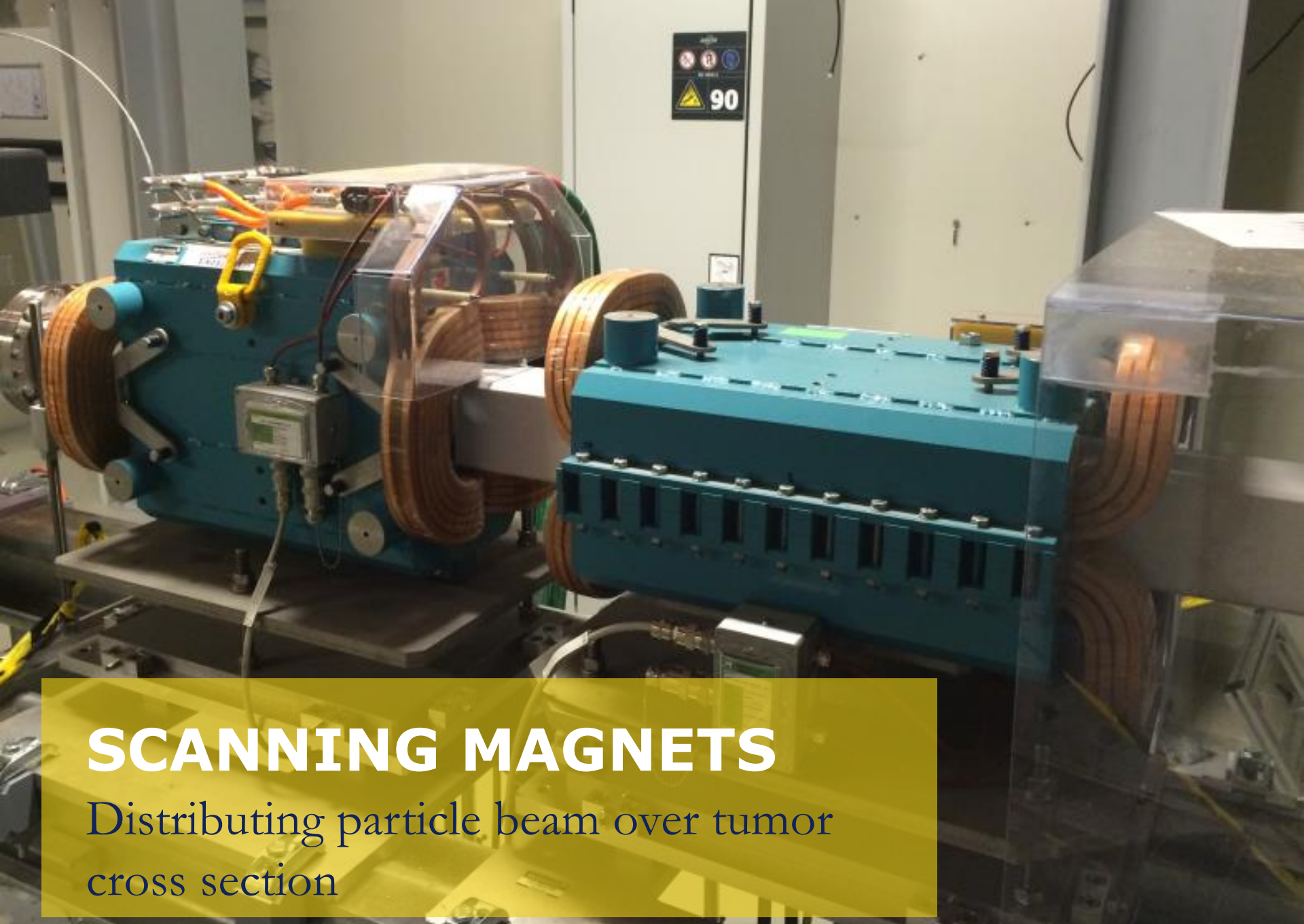
Guiding and focusing of particle beam





Beam Diagnostic Devices

Eyes of the physicist



SCANNING MAGNETS

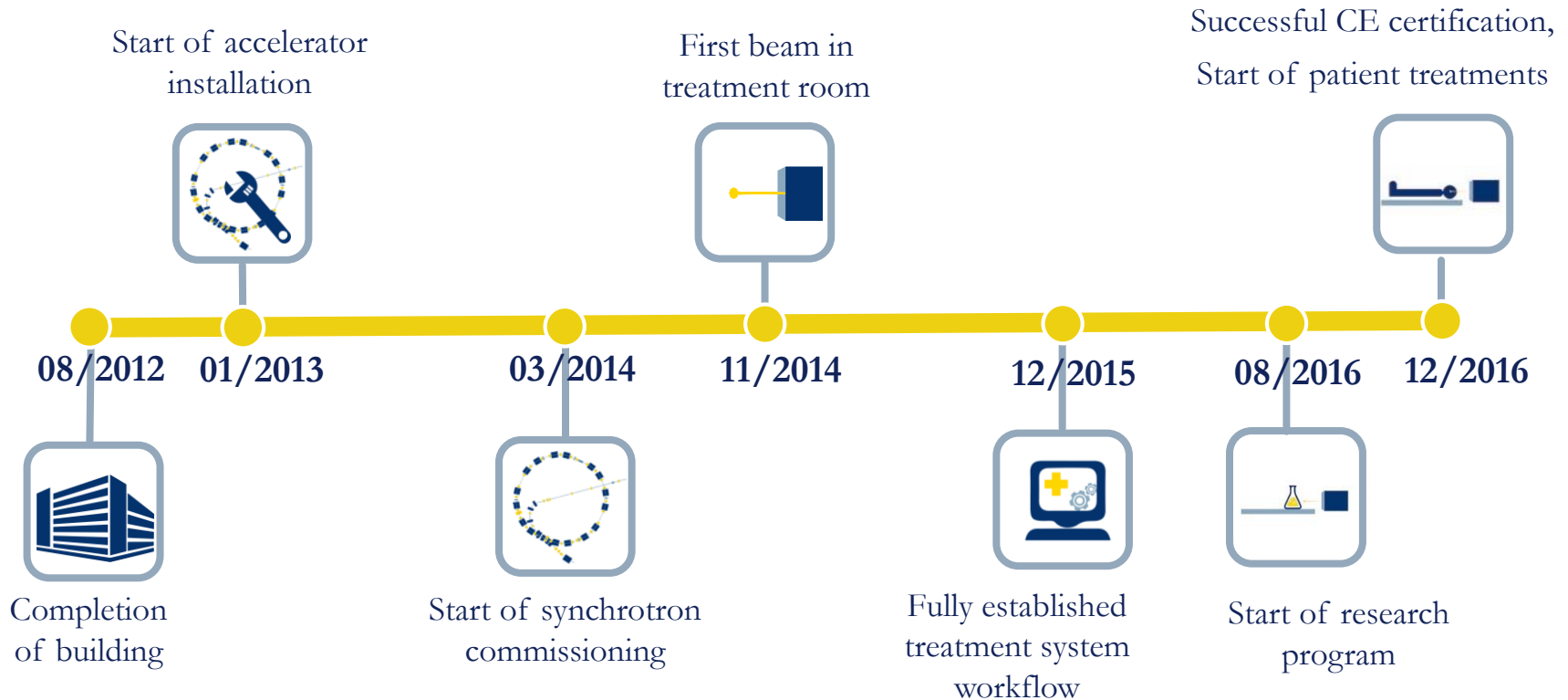
Distributing particle beam over tumor cross section

INJECTOR TEST STAND @ CERN

Proof of principle for the injector



From concept to clinical operation



OUR FACILITY

Irradiation Rooms

Three rooms for patient treatment

Research

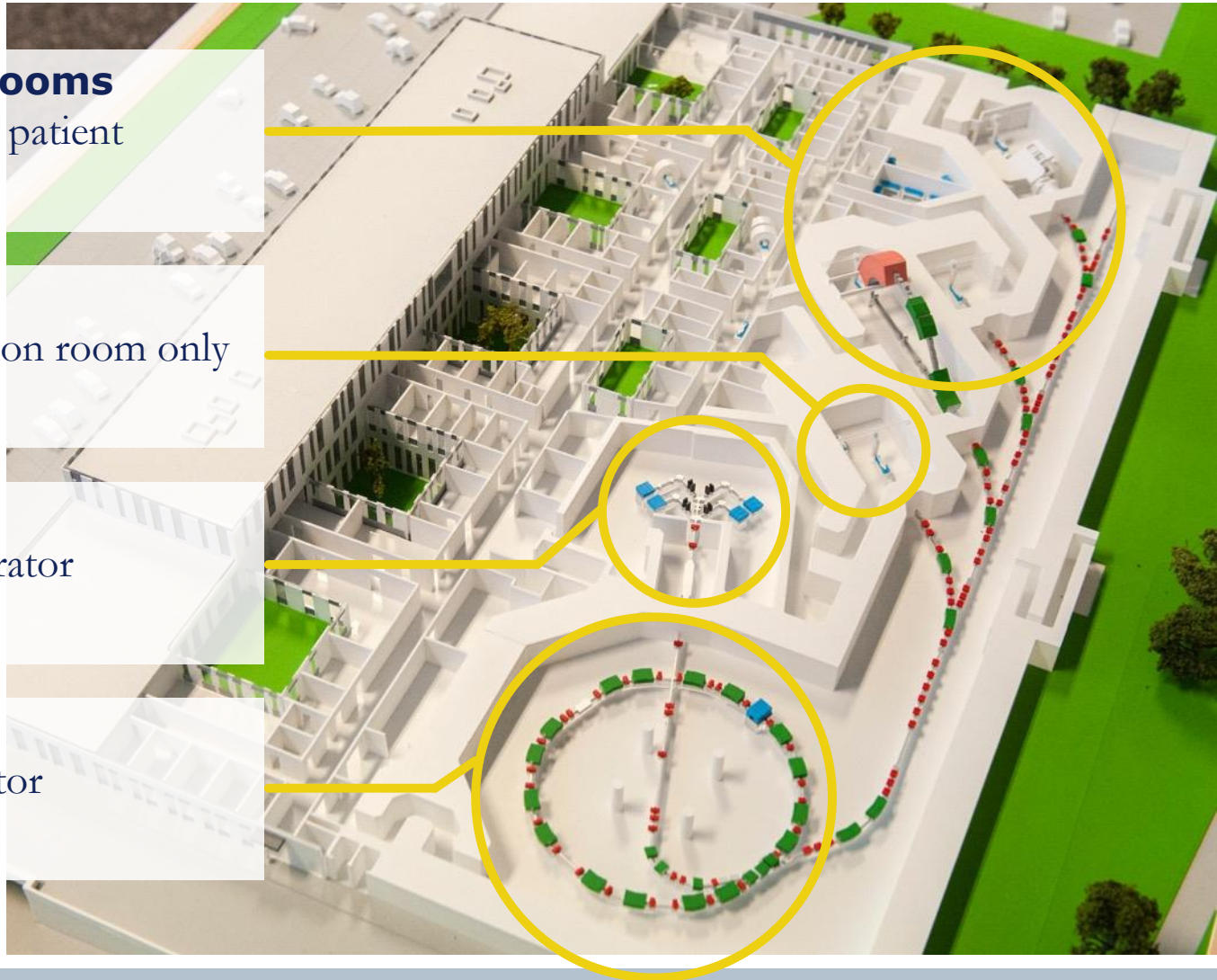
Separate irradiation room only for scientific use

Ion Sources

and linear accelerator

Synchrotron

Circular accelerator

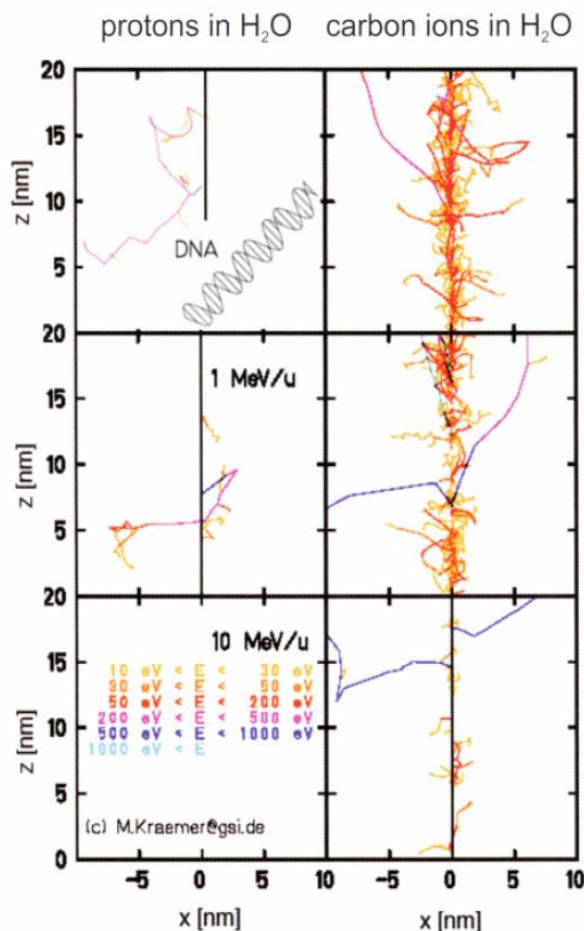


THE TECHNOLOGY

To generate **protons AND carbon ions**, a specific accelerator is necessary.

To guarantee highest precision and safety for patient treatment, state-of-the-art medical technology is used at MedAustron.

CARBON IONS – DIFFERENCES COMPARED TO PROTONS



PROS:

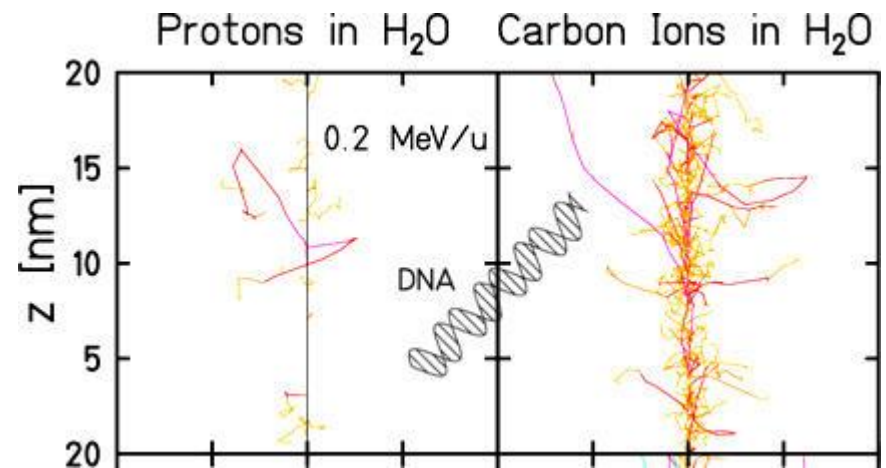
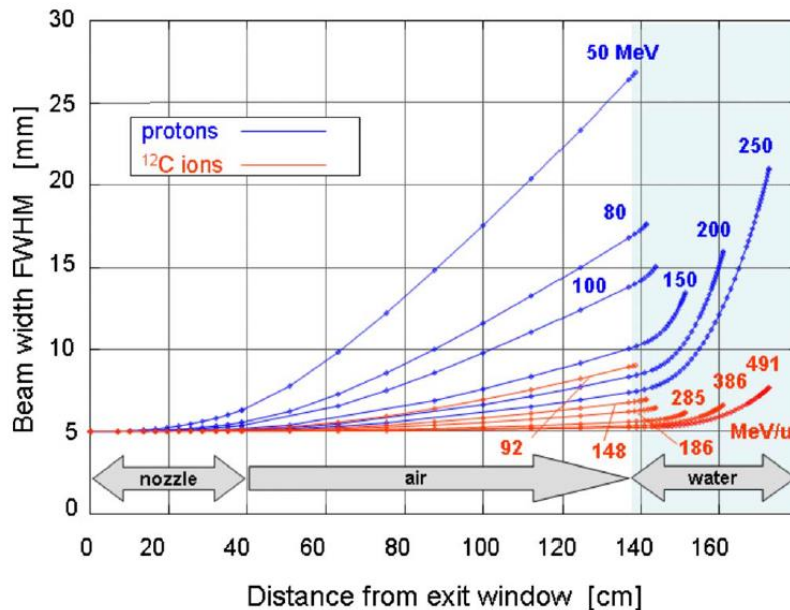
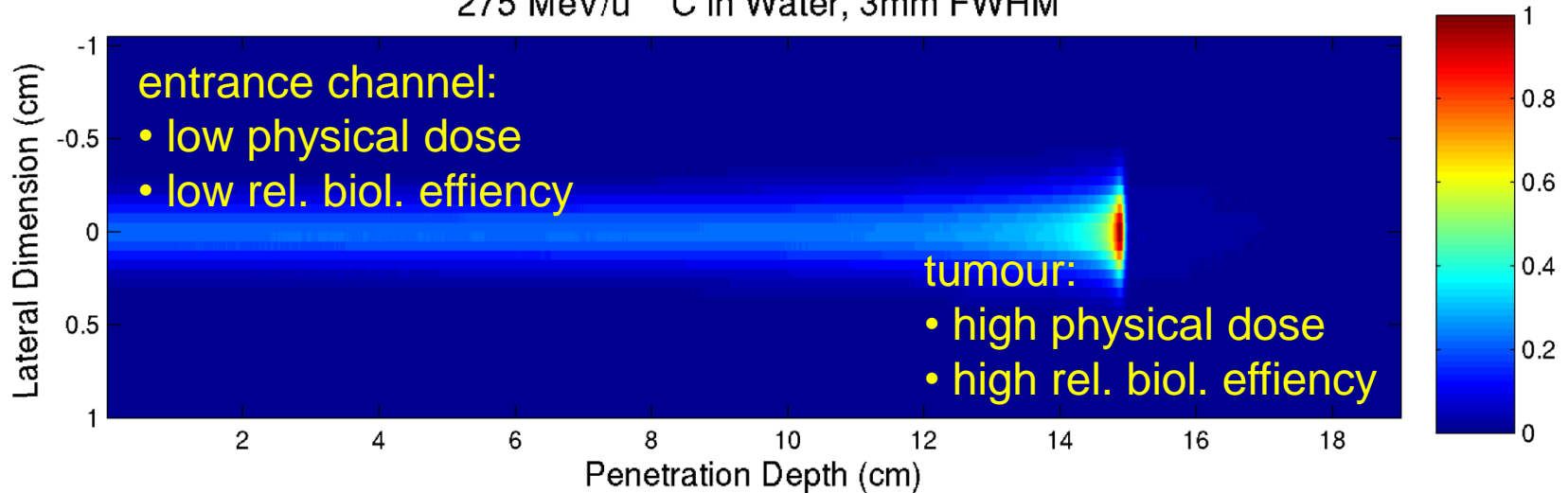
- Higher and energy dependent LET
- Higher and energy dependent RBE
- Less scattering
- Lower dependency on the cell cycle
- Increased effectiveness in case of radiation resistant tumor (hypoxic tumors)
- Improved dose conformity
- Potentially lower fractionation scheme

CONS:


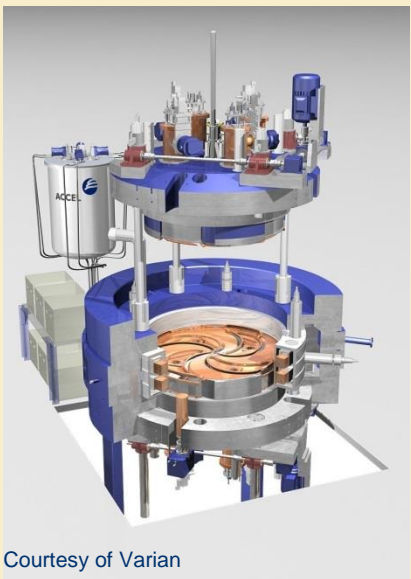
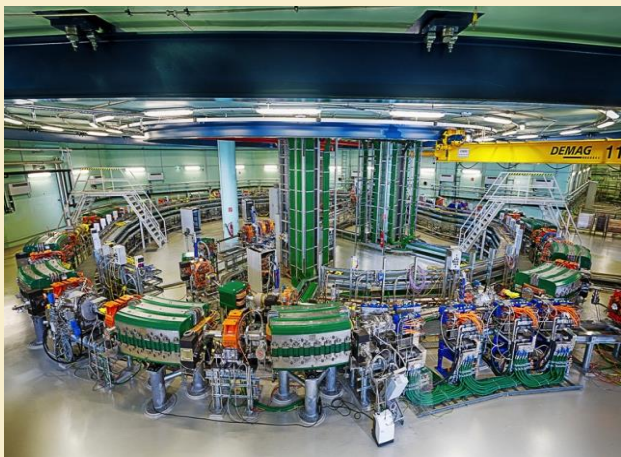
- Increased fragmentation tail
- Less experience compared to protons (~ factor 10)
- Lower acceptance in the community

Rational for carbon ions

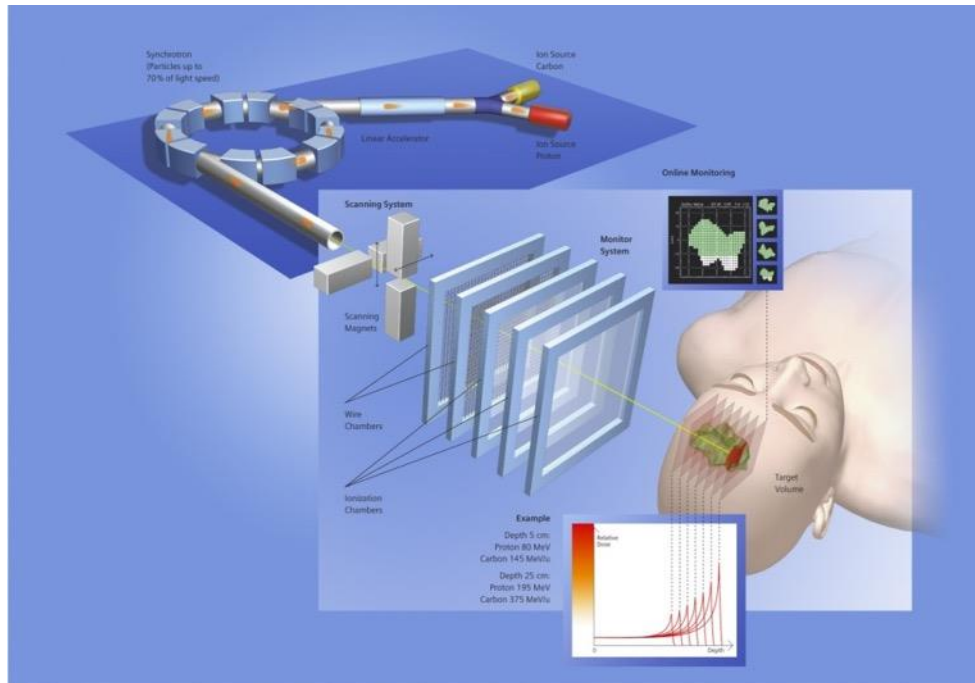
275 MeV/u ^{12}C in Water, 3mm FWHM



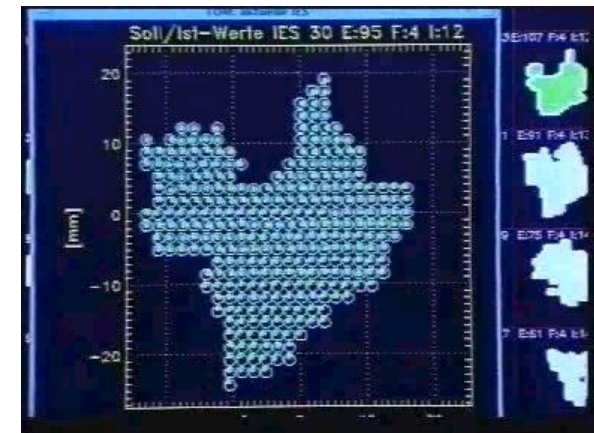
RADIOTHERAPY

	Conventional Radiotherapy	Proton Therapy	Ion Therapy
Accelerator type	<p>Electron Linac</p>  <p>Courtesy of Varian</p>	<p>Cyclotron</p>  <p>Courtesy of Varian</p>	<p>Synchrotron</p> 
Particle type	Electrons, photons	Protons	Ions (protons, carbon ions)
# Austria	> 40	0	1 (2016)
# World	x000	~ 60	6 (incl. MedAustron)

IRRADIATION CONCEPT



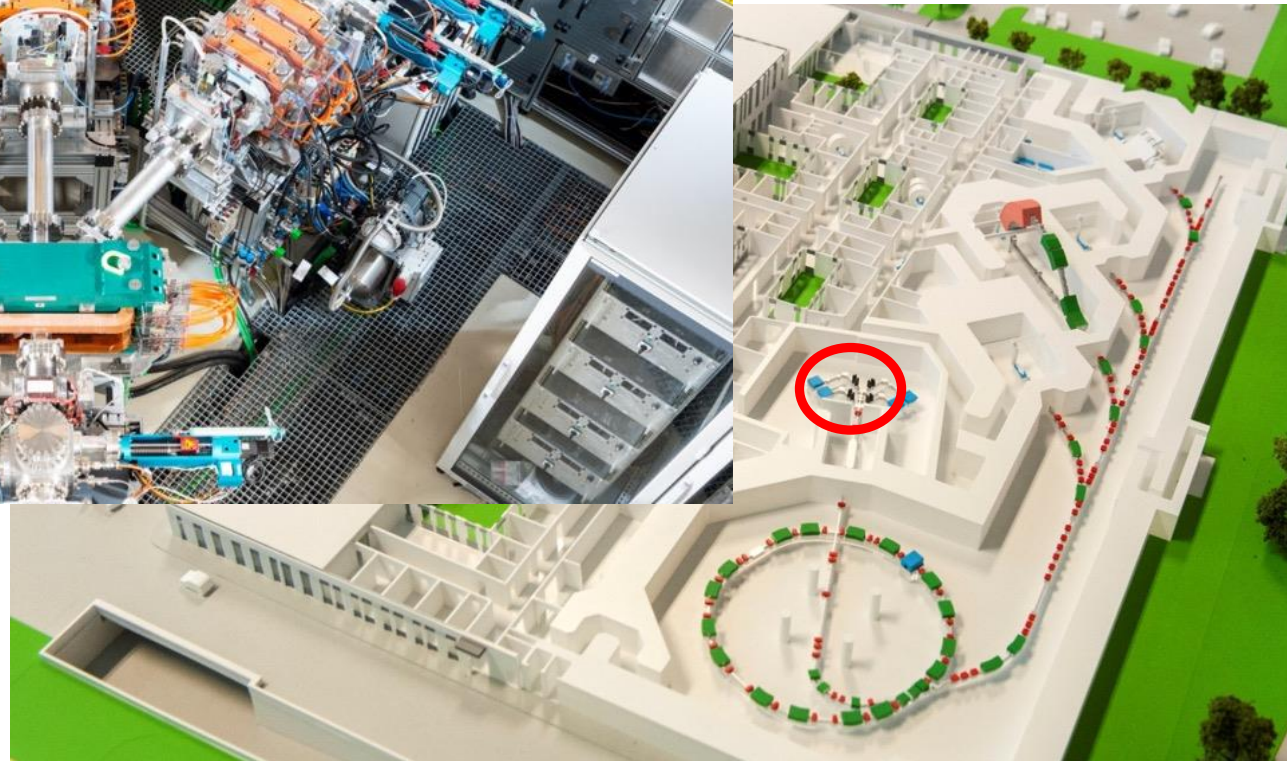
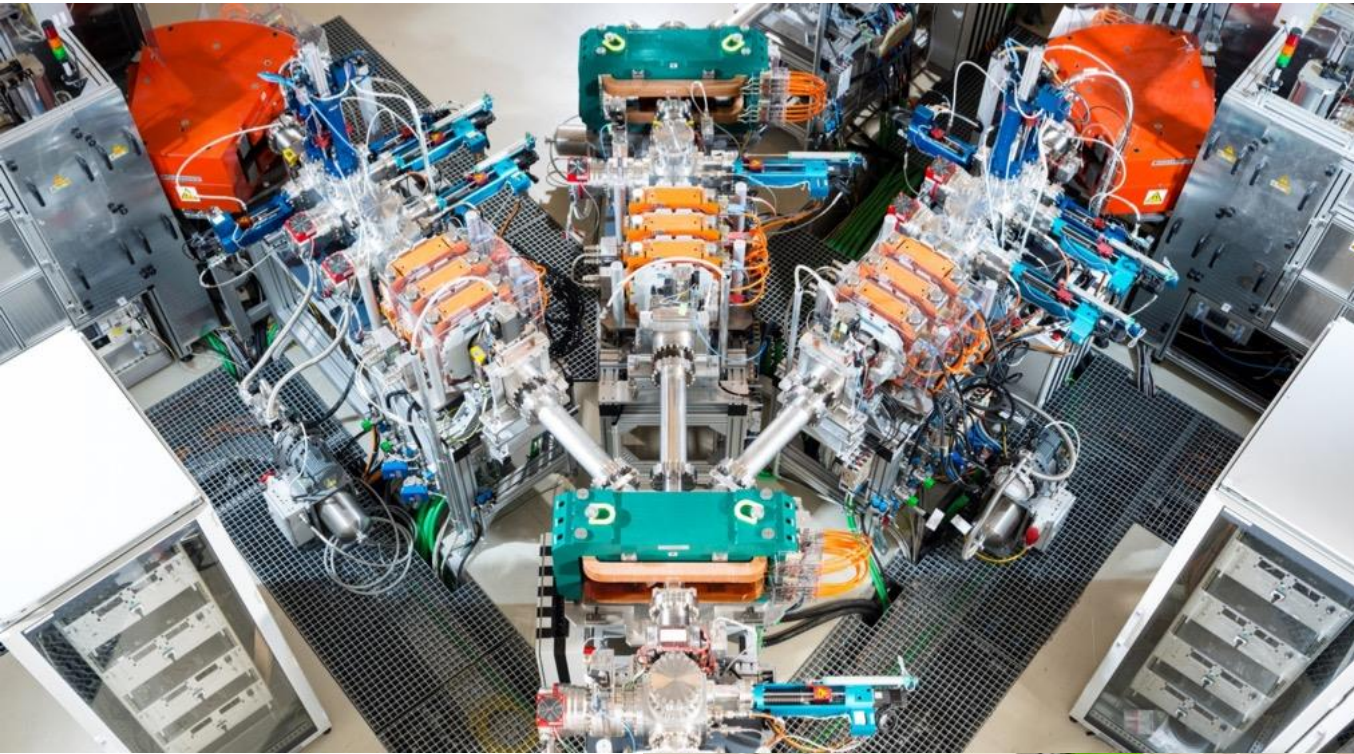
- active energy selection
-> penetration depth
- transverse pencil beam scanning
- online beam monitoring



Courtesy of GSI

SOURCE ROOM

Generation of protons and carbon ions





LINEAR ACCELERATOR

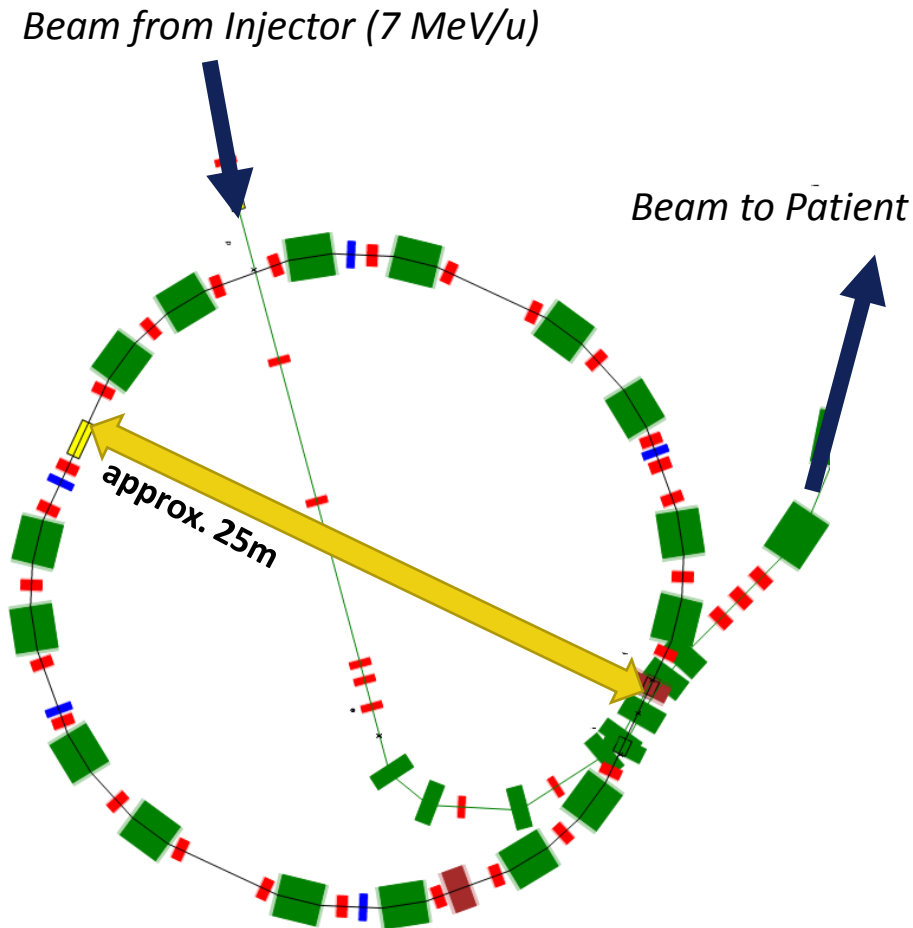
First step of acceleration

SYNCHROTRON

Acceleration up to 200,000 km/s



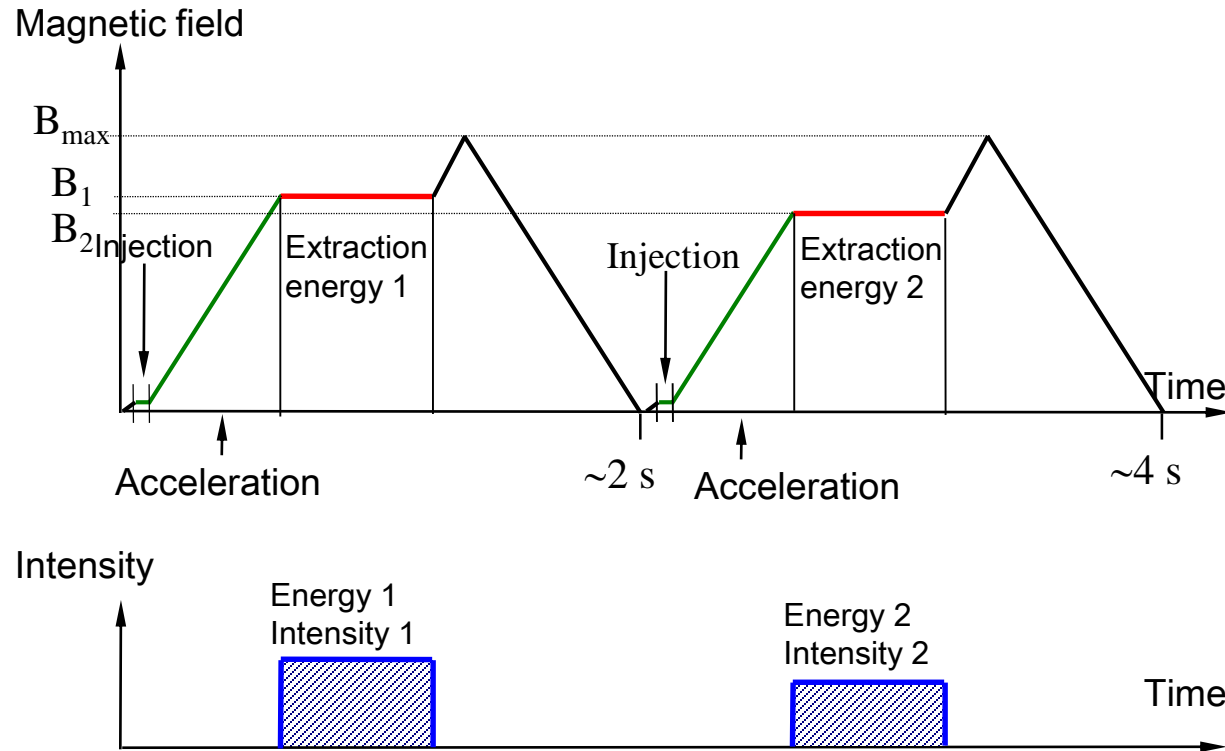
SYNCHROTRON



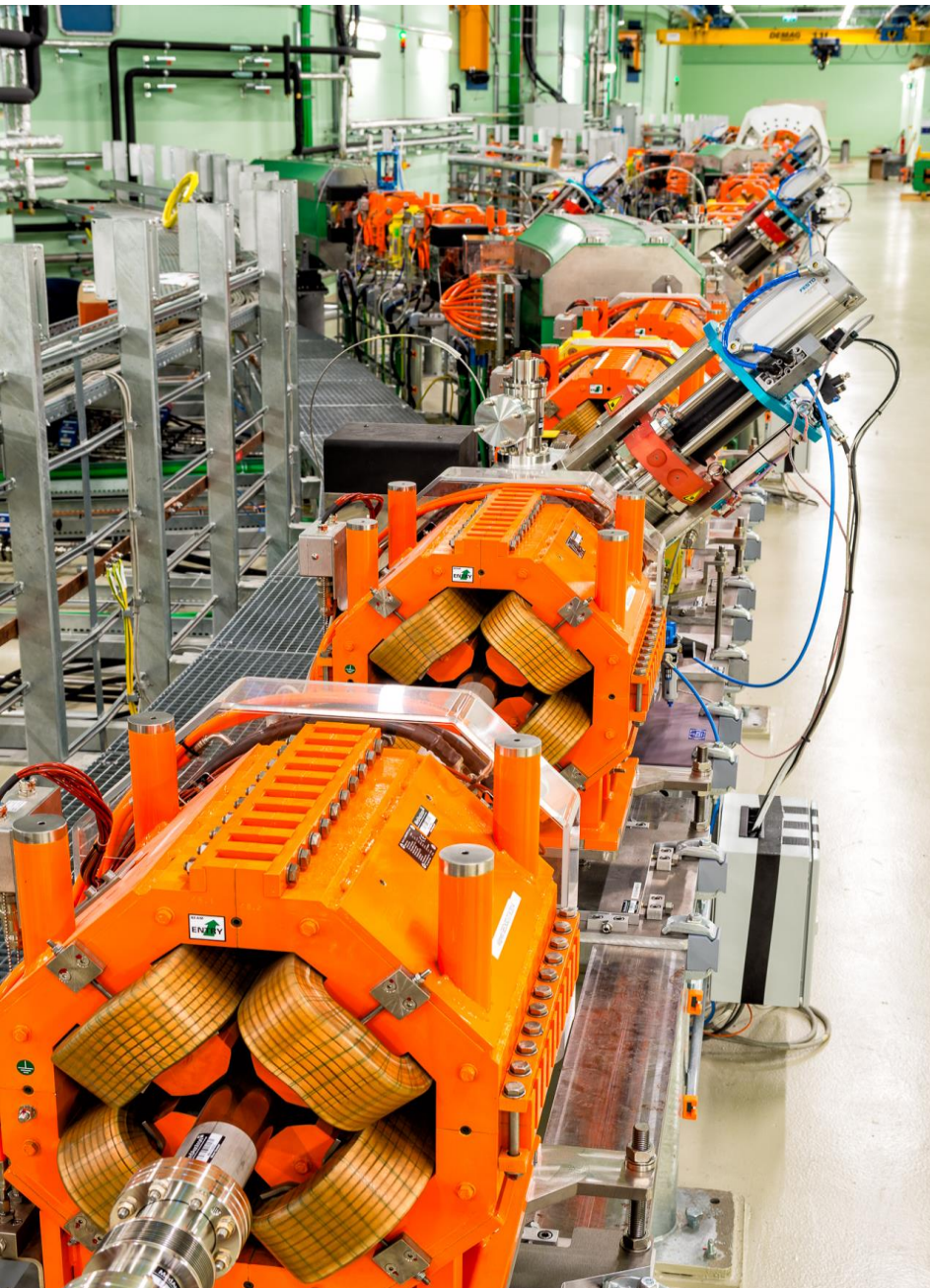
- Acceleration of beams to desired extraction energy
- Active energy selection:
 - 255 selectable energy steps (steps of 1 – 2 mm)
 - p: 60 – 250 MeV (NCR: 800 MeV)
 - C: 120 – 400 MeV/u
- Ramp speed: 0.5 s to highest energy
- Extraction time: 1 – 10 s

SYNCHROTRON

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



- Beam structure: pulsed, energy and intensity variable

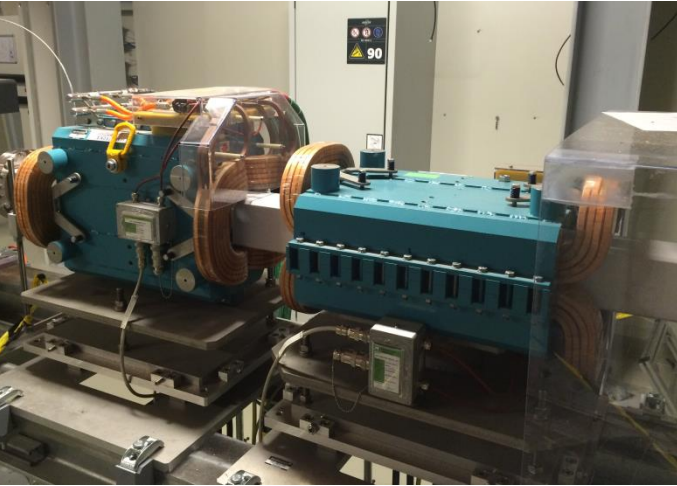


TRANSFER LINES

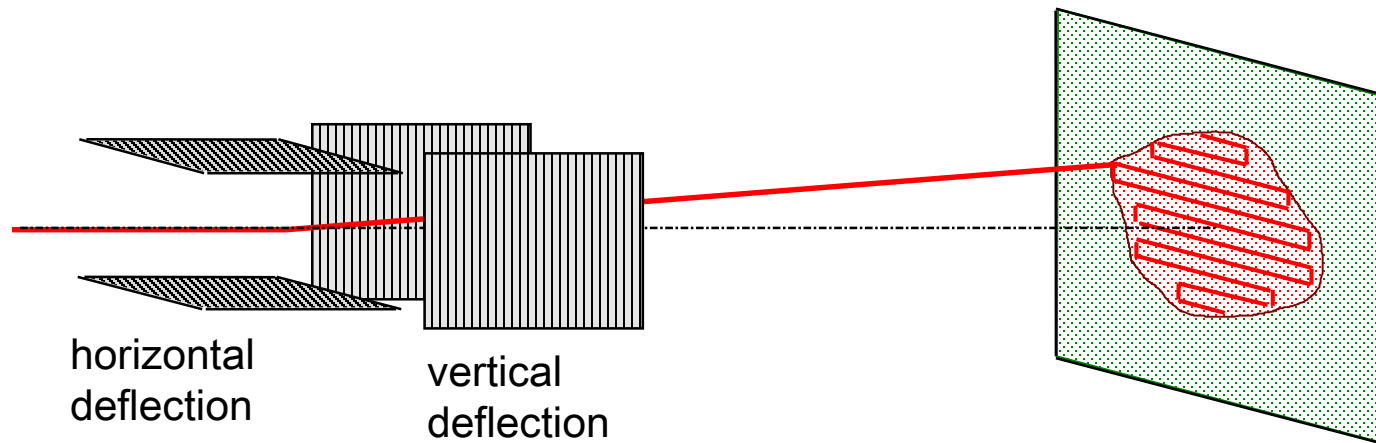
Guiding the particles to the irradiation rooms



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)





PROTON GANTRY

Offering beam irradiation angles of larger 180 degrees

PARTICLE ACCELERATOR

Key figures

- developed in close cooperation with CERN (European Organisation for Nuclear Research)
- 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

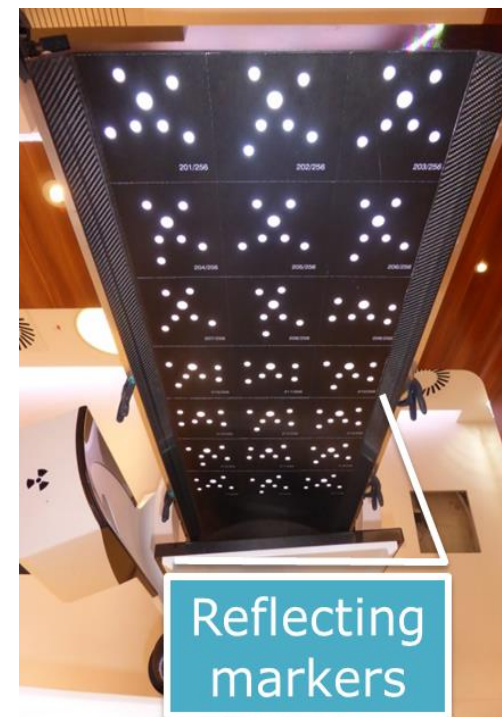
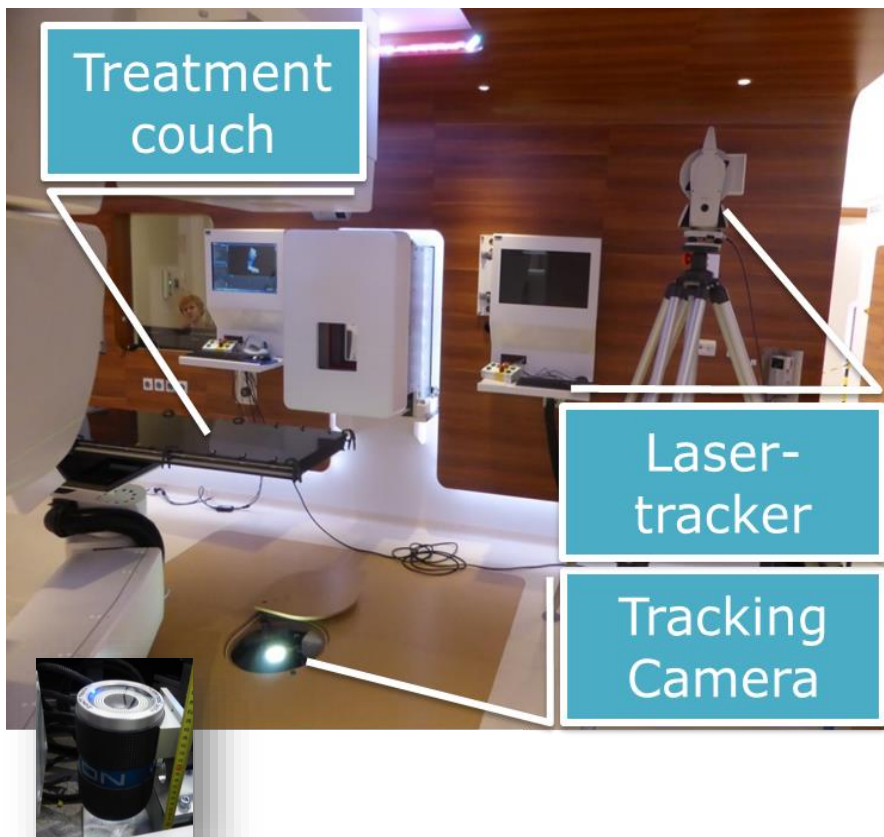


PATIENT POSITIONING

in the millimeter domain

PATIENT POSITIONING SYSTEM

- 7DOF ceiling mounted robot positioner
- High resolution tracking for feedback loop based positioning and surveillance



PATIENT POSITION VERIFICATION

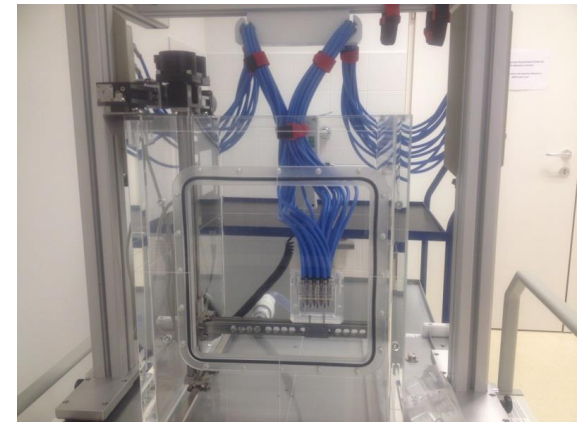
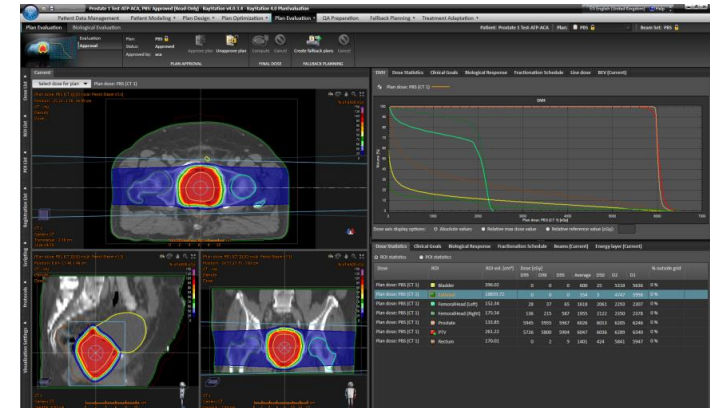
- Flat panel and X-ray tube rotatable around the ring, couchmounted
- fast flat panel detector (30 Hz framerate)
- single source dual energy X-ray (60, 120 kV)
- large clearance (78 cm ring)
- 2D, 3D imaging
- cone beam CT



PATIENT WORKFLOW

Happening once:

- ☐ Introductory talk
- ☐ Diagnostic: CT/MR
- ☐ Immobilization aids (patient specific!)
- ☐ CT/MR for treatment planning (in treatment position)
- ☐ Therapy planning
- ☐ Plan verification



DAILY PATIENT WORKFLOW

Daily irradiations (fractions: 20 – 40 tumor dependent):

- ❑ Patient positioning
- ❑ Position verification (2D/3D or 3D/3D)
- ❑ Irradiation
- ❑ Ev. adaptive Therapy planning



DAILY PATIENT WORKFLOW – IN ROOM TIME

Example: CNS or base of skull tumor

Step	Dur. (min)
Preparation, Positioning and Verification	11
Irradiation (2 portals including robot movement)	16
End of treatment (release of patient, move robot to step off position, patient exit)	5
Sum	32

A TYPICAL CLINICAL DAY @ MEDAUSTRON

Patient treatment: Mo – Fr from 8am – 6pm, presently: 27 patients

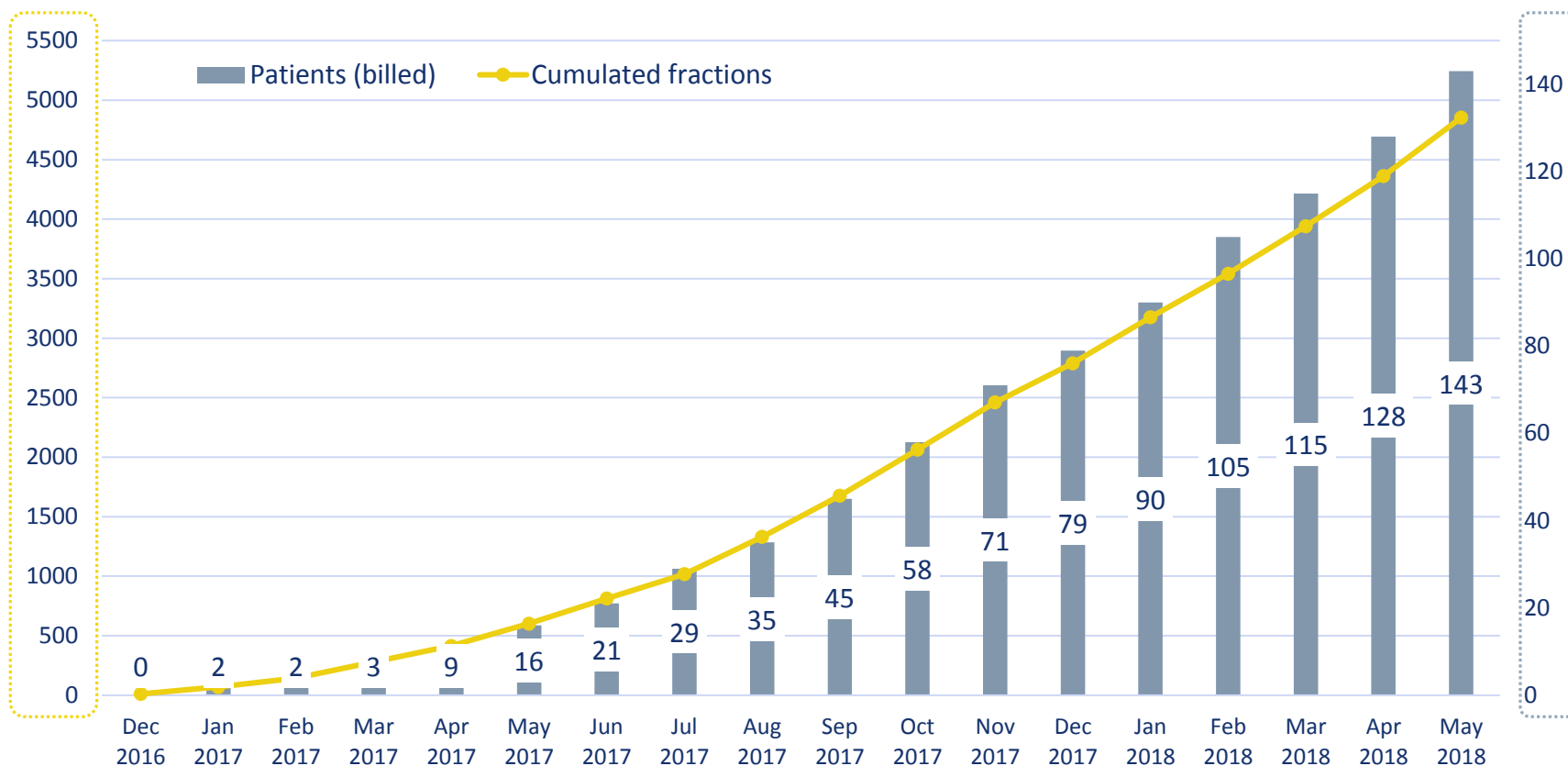
- ❑ 4:30 am: Start of accelerator QA
- ❑ 6 am: Handover to medical physics
- ❑ 6 – 8 am: QA by medical physics (3 beam lines, protons only)
- ❑ 8 am - 6 pm: patient treatment
- ❑ 6 – 10 pm: patient specific QA, machine development, etc..
- ❑ 10 pm – 4:30 am: commissioning, development

Weekends:

- ❑ Commissioning, development, research, service slots

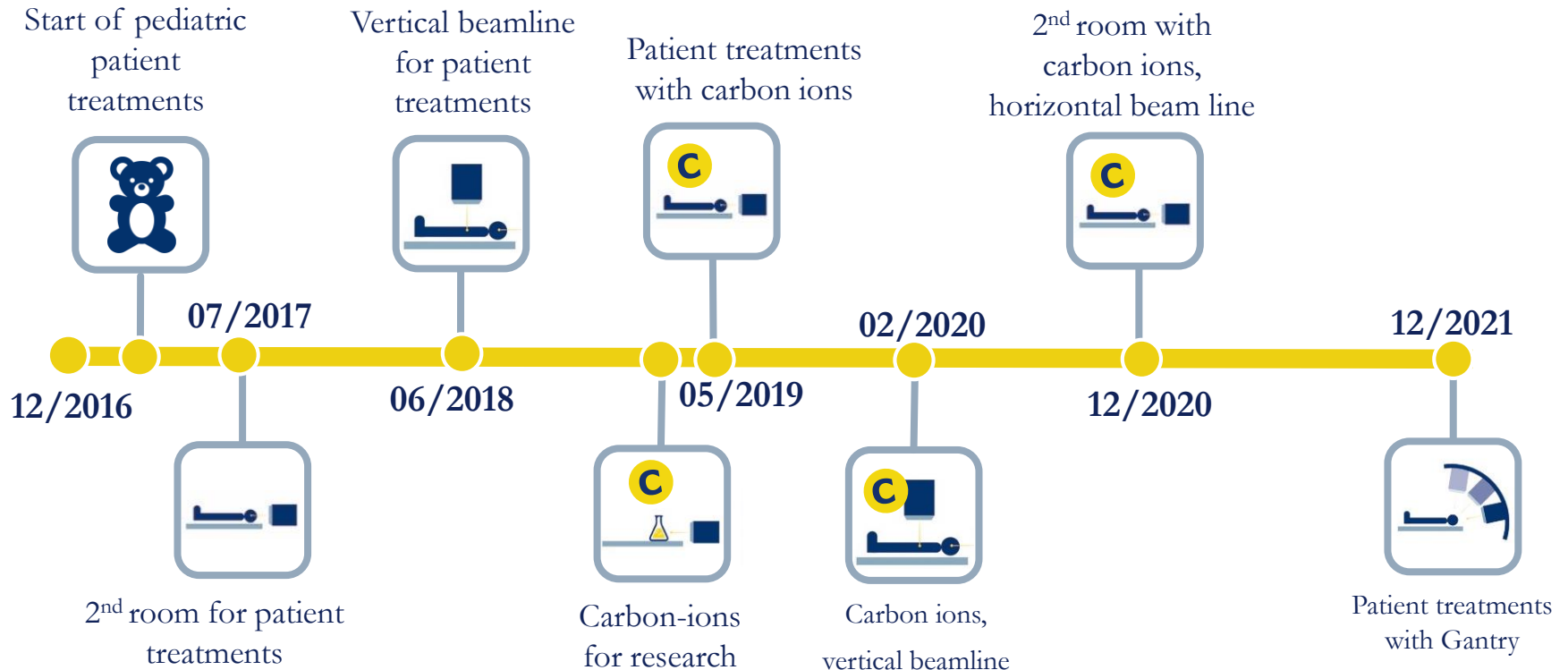
PRESENT STATUS

- Presently 27 patients/day (from 8am – 6pm)
- 2 rooms in operation (H/V) with protons only



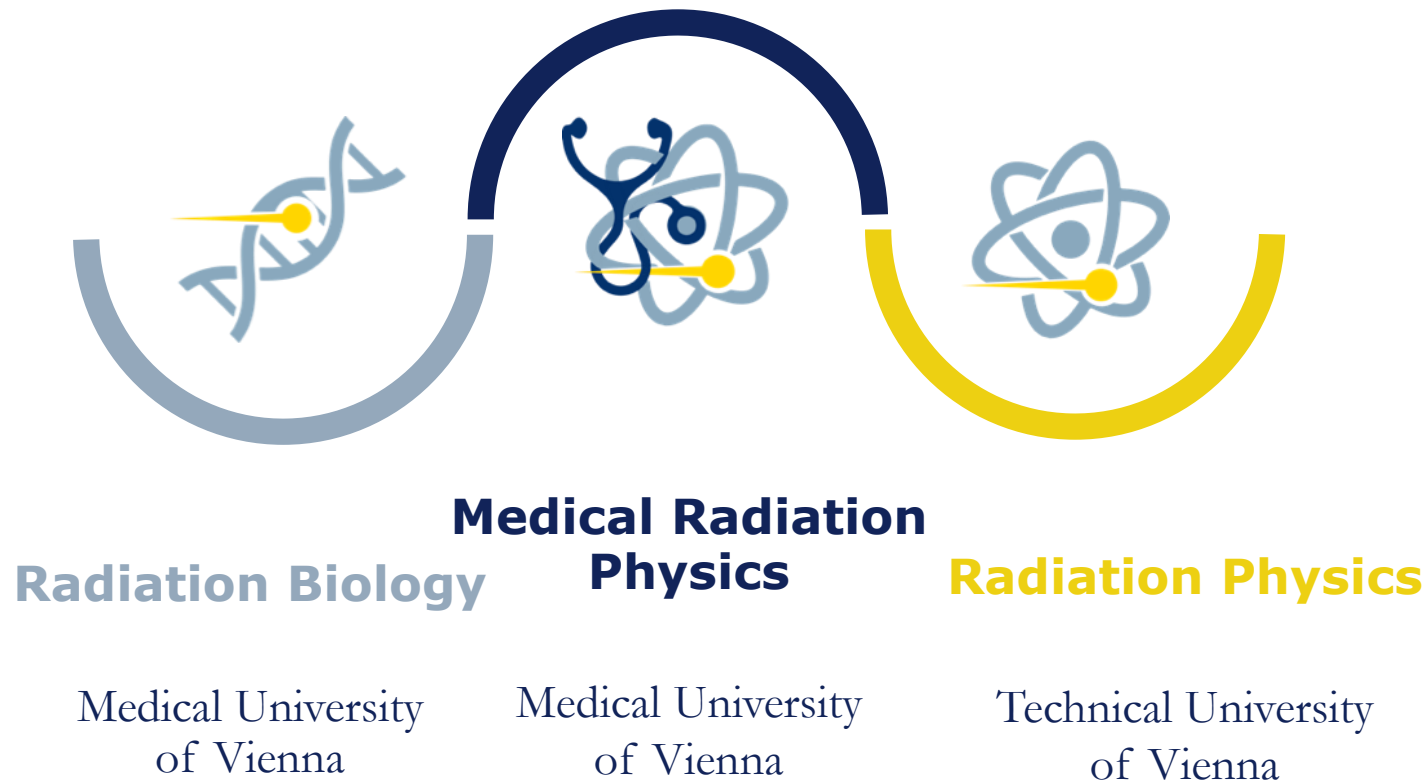
Status and Outlook

- Commissioning of further modalities (beam lines, ion species) in parallel to clinical operation.
- Full operation by end of 2021.



RESEARCH @ MEDAUSTRON

- Close connection to the medical and technical universities of Vienna
- 3 professorships



RESEARCH @ MEDAUSTRON



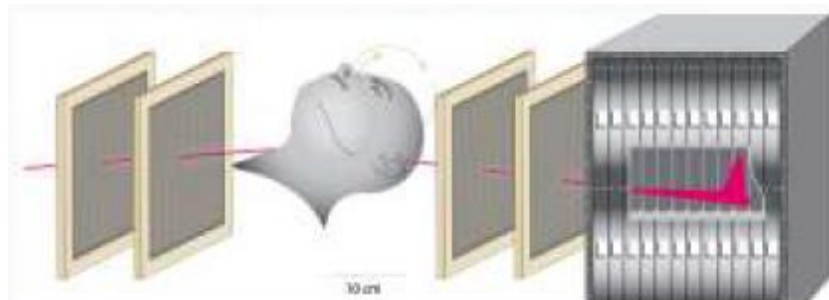
Focus on translational research:

- Intrafraction Adaptive Radiation Therapy:
 - CBCT implementation, dual energy for 3D/3D image registration and adaptive treatment planning
- Interfraction Adaptive Radiation Therapy:
 - Moving targets (breath hold techniques, surface scanner,...)
 - Tracking of tumor target

RESEARCH @ MEDAUSTRON

Focus on translational research:

- Imaging with Ion Beams (proton CT):
 - Use same particle for imaging, planning and treatment
 - Direct measurement of stopping power, no conversion in HUs



- Energy Transfer Mechanisms and Applications in Biology and Physics
 - cell and tissue culture studies



RESEARCH @ MEDAUSTRON

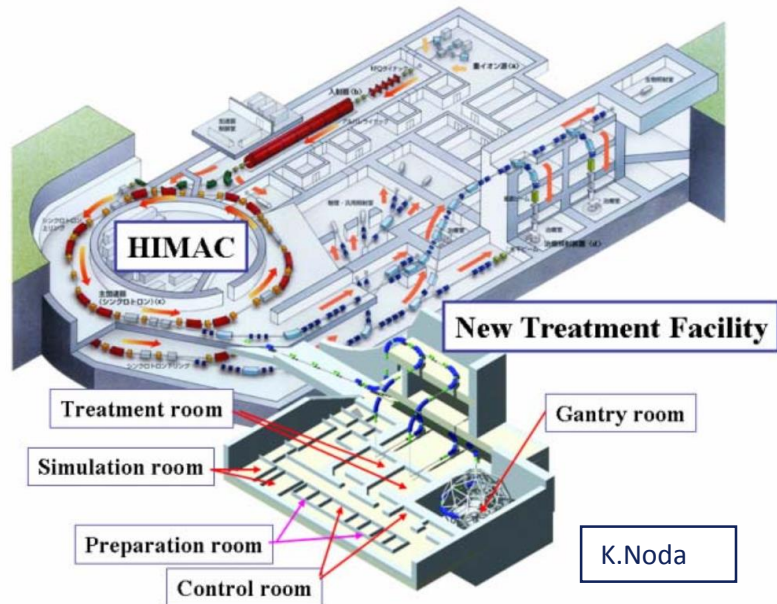
Focus on translational research:

- MR-Guided Proton Therapy
- Pre-Clinical Animal Research



Presently only 5 shifts (40h) for research per month.
At maximum 14 shifts/month.

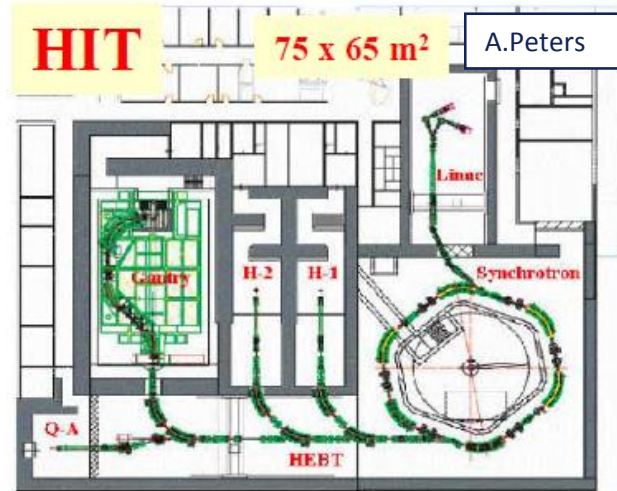
TREATMENT FACILITIES



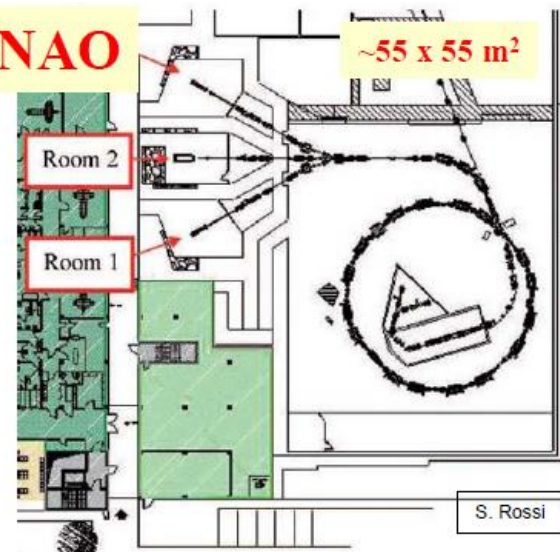
IBA



R. Verbruggen, JUAS 2012



CNAO

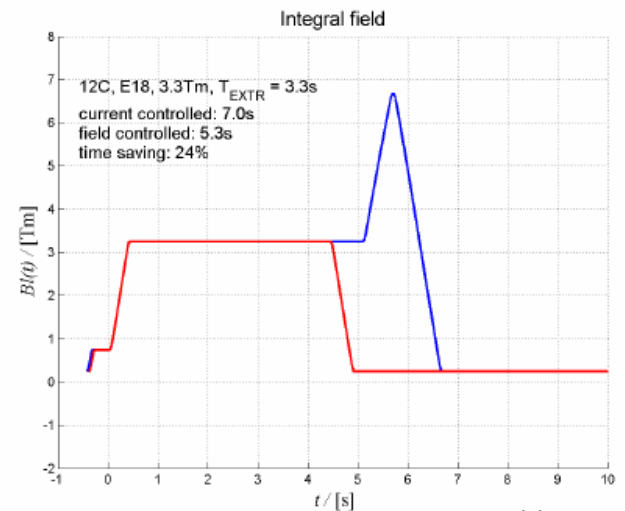


THE STATE OF THE ART FACILITY

- **Multiple ion species (p, He, C)**
- **Synchrotron Cycle time optimized**
 - Cycle compression
 - Dynamic spill time
- **Gating**
- **Field regulation**
- **Multi Energy Extraction**
- **Dynamic Intensity Control**
- **3D dose online tracking**
 - Prompt Gamma Imaging
 - C11 beams – online PET

THE STATE OF THE ART FACILITY

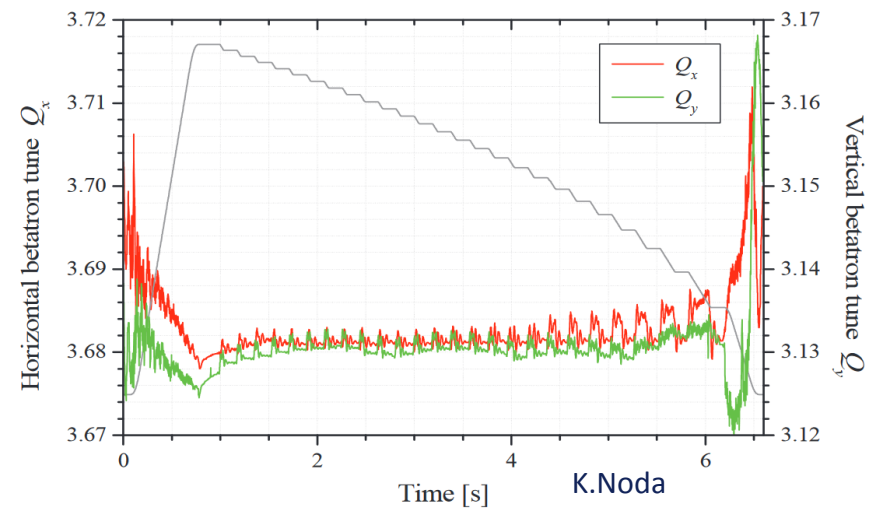
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E.Feldmaier

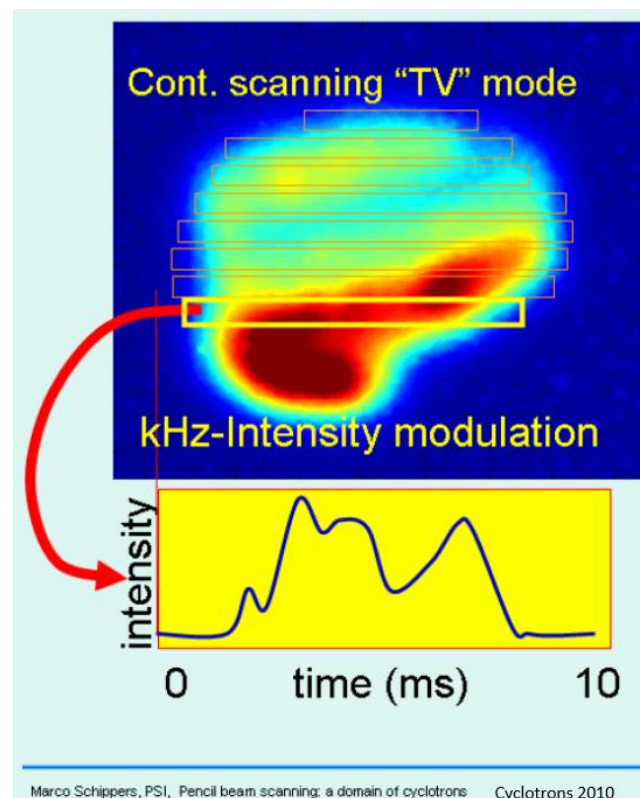
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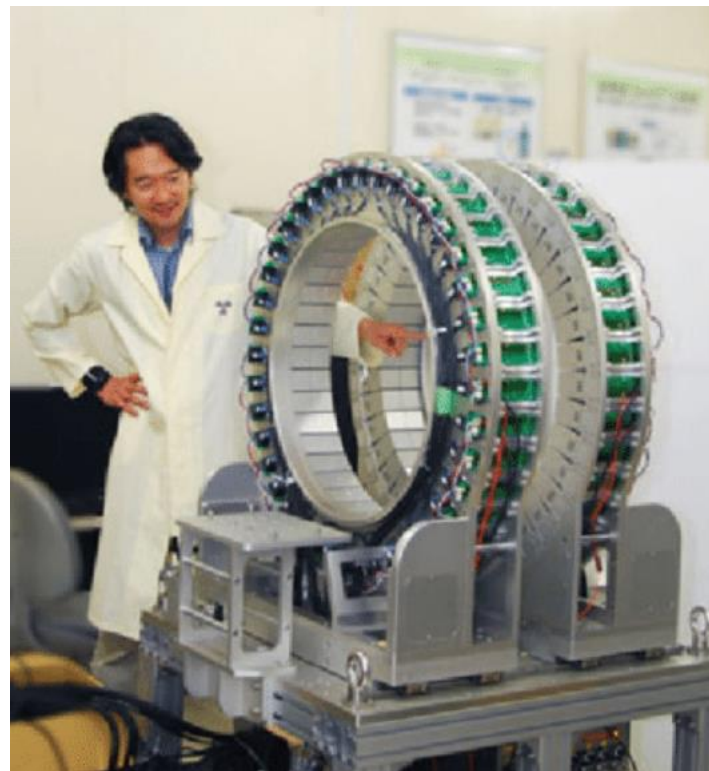
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THE STATE OF THE ART FACILITY

- **Multiple ion species (p, He, C)** ✓
- **Synchrotron Cycle time optimized** ✓
 - Cycle compression
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- **Field regulation** ✓
- **Multi Energy Extraction** ✓
- **Dynamic Intensity Control** ✓
- **3D dose online tracking** ✗
 - Prompt Gamma Imaging
 - C11 beams – online PET

CONCLUSIONS

- MedAustron is a synchrotron based centre for ion therapy for cancer treatment and research, one out of four centres in Europe.
- About 10 years from company foundation to treatment of first patient.
- Presently commissioning and development of further treatment modalities in parallel to clinical operation and research activities.
- Manufacturer of a CE labelled medical accelerator and technology provider of particle therapy systems
- Provider of training for radiation oncologists and medical physicists.

MedAustron

THANK YOU
**for your
attention!**

www.medastron.at

MedAustron