Ion Beam Centres Optimization study: Treatment time reduction

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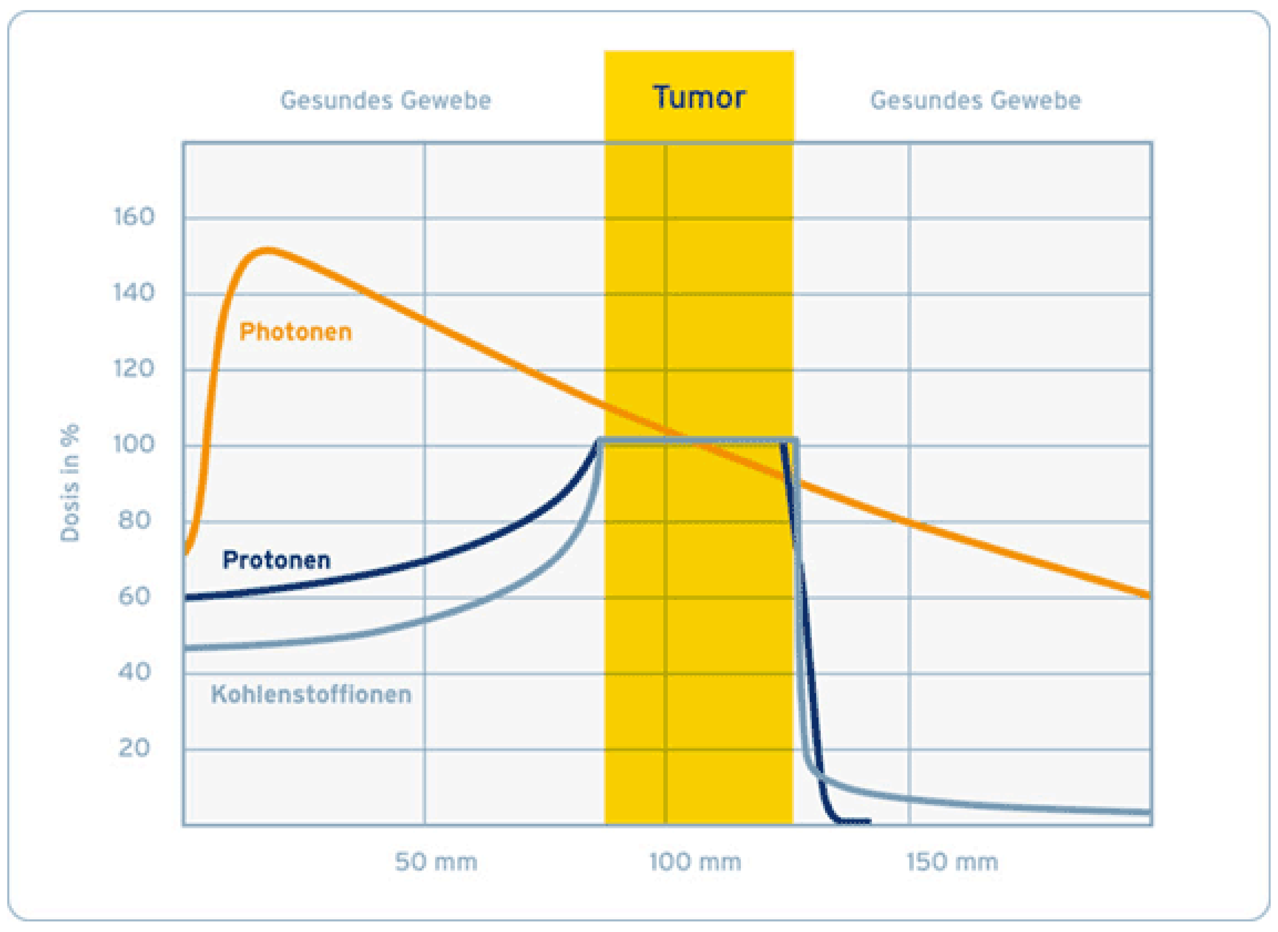
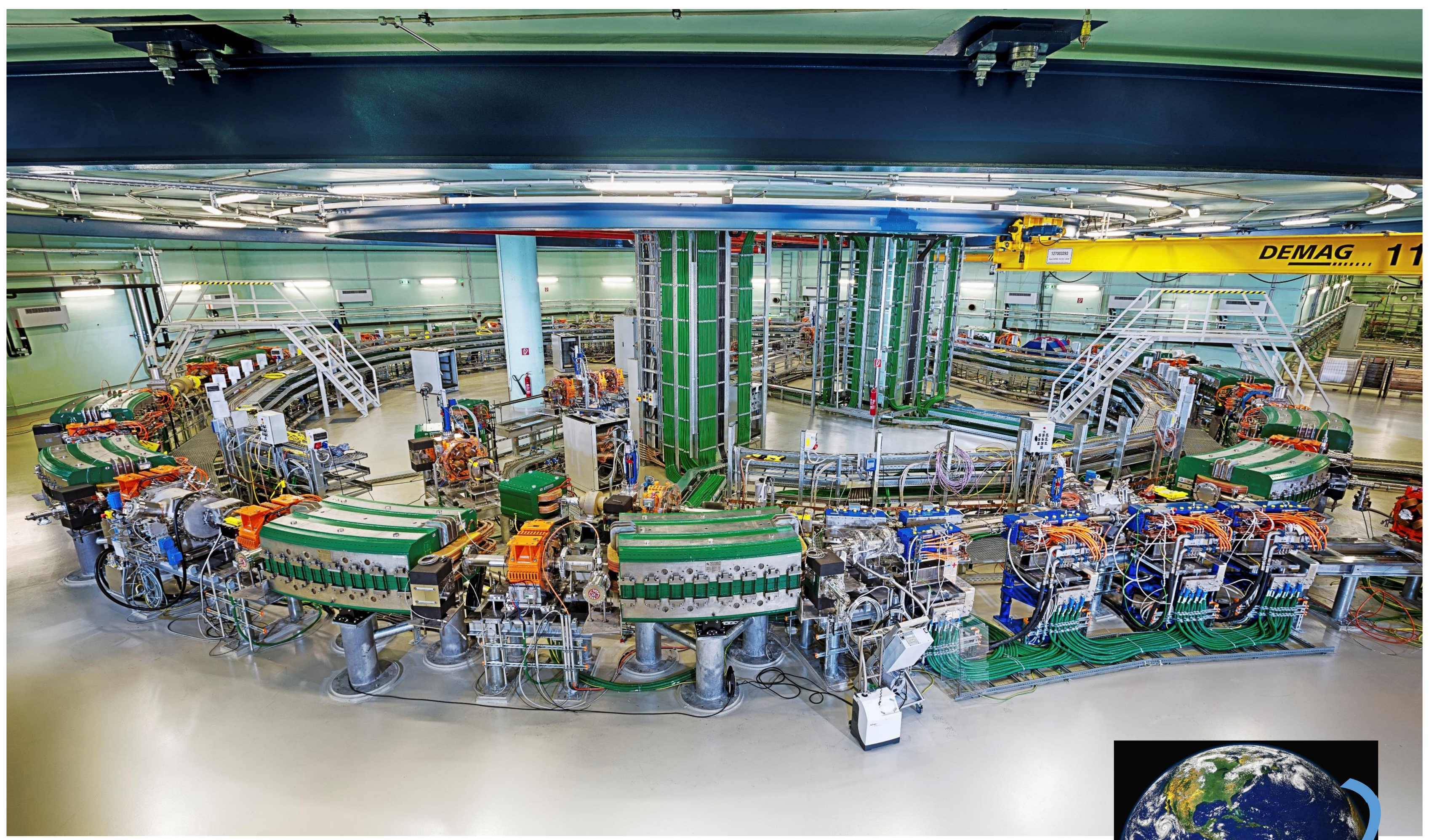
Ion beam therapy centres

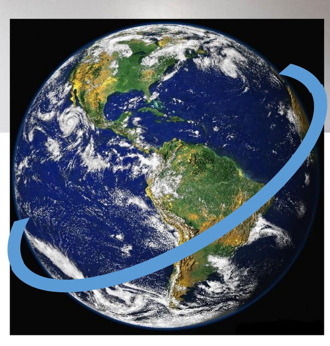
Proton beams can be used to focus the irradiation treatment to very specific lesion area, maximising the damage to tumour, while minimizing secondary effect on healthy tissues.
Carbon beams offer an even more effective solution, especially for a series a radio-resistant tumour that can survive even very high doses of photons or protons.



Dose deposited inside tissue with photon, proton and Carbon based therapy.
Credit: EBG MedAustron GmbH

Carbon nuclei are 12 times heavier than a proton and we need very large machines to accelerate them to energies relevant for ion beam therapy.
Nowadays the only machine demonstrated to be able to do so are synchrotrons. The particles are bend in a circular trajectory and accelerated a little every turn. After less than a second, the particles complete millions of turn and reach sufficient energy to be able to penetrate in the patient body and damage the lesioned tissue, sparing the healthy organ from unnecessary damage.

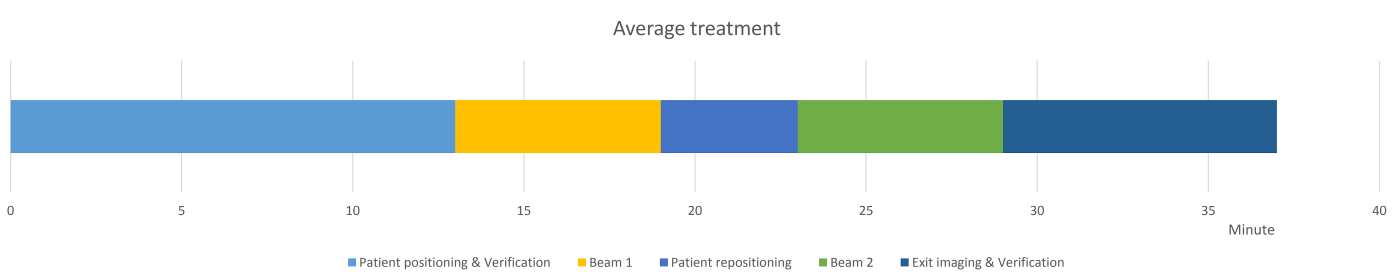




Synchrotron installed at MedAustron, 77m of circumference. In less than a seconds, particles travel the equivalent distance of many times the Earth circumference!!!
Credit: EBG MedAustron GmbH(left), modified from NASA Goddard Space Flight Center's Blue Marble (right)

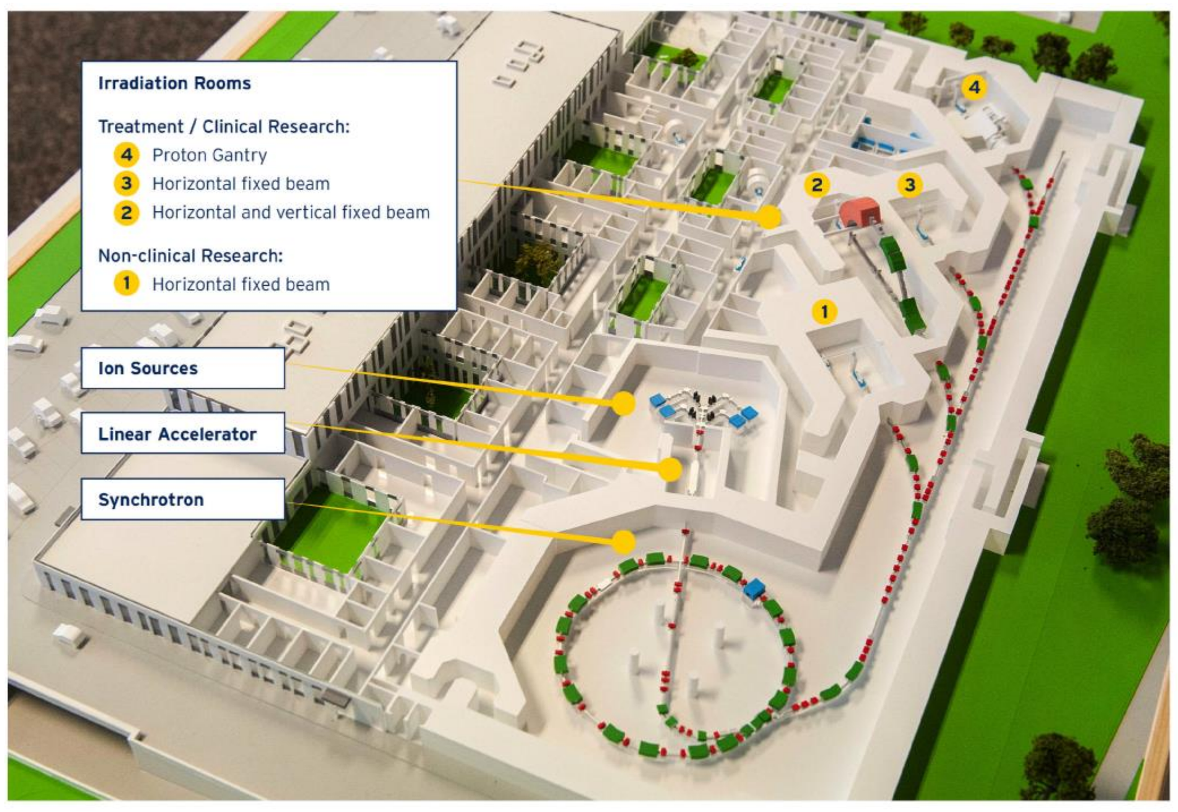
Research Motivation: Treatment time

Synchrotron based facilities are very flexible, but typically have a low duty cycle because some time is lost in accelerating and preparing the beam and the machine to ensure quality and reproducibility of the treatment.
This naturally lead to a longer time necessary to complete the therapy.
Scope of my research is to find how we can shrink the treatment time while even boosting the quality of the delivered beam and ultimately be able to treat more patient.



Study case: MedAustron

MedAustron is one of the handful centres in the World built to be able to provide therapy with both carbon and proton beams.
It is based from a study initiated at CERN and shares most of its design with CNAO in Pavia, Italy.
A 77m circumference synchrotron supplies 3 irradiation rooms with high quality and precision beam of proton and carbon for patient treatment. An additional room is dedicated to non clinical research.
Patient receive proton beam therapy at MedAustron since December 2016, meanwhile commissioning of clinical quality carbon beam is in progress. A facility-broad research and development program is running in parallel, with the goal of optimise performance and maximise patient throughput.



Schematic view of the MedAustron facility, in Wiener Neustadt, Austria.
Credit: EBG MedAustron GmbH

Treatment time reduction: How to?

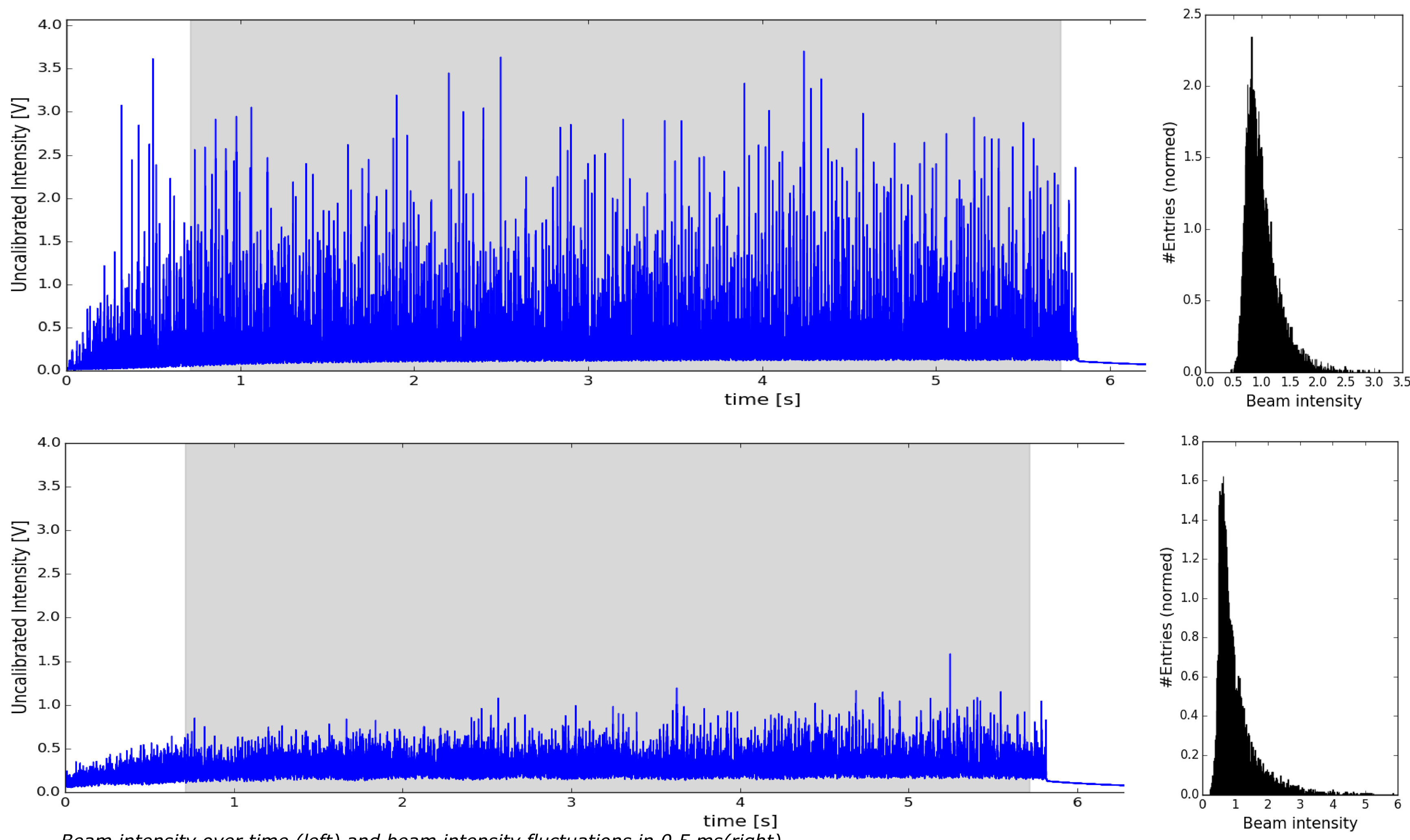
The time necessary for a treatment session can be reduced in a numbers of way:

- faster acceleration
- shortening of the period necessary to ensure reproducibility of magnet behaviour
- reduction of dead times
- higher beam efficiency
- higher beam intensities

To achieve any of the above we need to modify the way the machine is operated and it is necessary to understand, control and optimise a number of phenomena of beam dynamics with dedicated studies of accelerator physics. Preliminary results of my research shows that it is possible to <u>decrease tenfold the time necessary to deliver the beam.</u>

Example: smoothening

Higher beam intensities can contribute to faster treatment, but due to very small and quick variations in magnet power supplies (fraction of one part in hundreds of thousand lasting a fraction of millisecond) the intensity of delivered beam fluctuate slightly. To maintain high quality and operate at very high safety standard, it is necessary to control the particle flux to the highest possible degree of precision and reduce the ripples to a minimum.
A technique called "RF-channeling" can be used to smoothen the extracted beam.
In this scenario a sinusoidal signal of few kV oscillating at a frequency of few MHz is applied to radio-frequency cavity in the synchrotron.
This electromagnetic wave interact with the beam to accelerate its extraction in the very last moment and mitigate the effect of power suppliers fluctuations.



Beam intensity over time (left) and beam intensity fluctuations in 0.5 ms(right) , without (top) and with RF-channeling (bottom)

Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 675265.