STATUS OF THE CARBON ION SOURCE COMMISSIONING AT MEDAUSTRON

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MedAustron Ion Therapy Center

INTRODUCTION

MedAustron is the synchrotron-based Ion therapy center in Austria. Accelerated proton beams with energies of 62-252MeV are used to treat patients with cancer since 2016. Carbon ion beam is currently under commissioning and will provide treatment in 2019 with energies of 120-400MeV/u. The Injector features three identical ECRIS from Pantechnik (Fig.1), two of which are used to generate the proton and the carbon beam with an energy of 8 keV/u. The generated beam is sent to a 400keV/u RFQ and a 7MeV/u H-mode Linac. Follows the injection in a 77m synchrotron, via a medium energy transfer line, where the energies for patient treatment are reached. The beam is sent to four irradiation rooms via a high energy transfer line, two of which are currently used for medical treatment.

Being a medical facility means we need to face different challenges than a research world. This includes fulfiling norms on safety, risk management, enviroment and radiation protection. This poster focus on those topics to provide another perspective on the source operation.

How medical environment affect maintenance requirements ?

Due to the legal restrictions, before the accelerator can be used for treatment, all components and parameters need to undergo long commisioning process. The parameters are fixed and beam properties are supposed to be very stable to fulfil strict requirements. Each violation is not only lost time but can possibly affect patient therapy. Important parameters are: uptime, short term stability, long term stability and safety.

Our Maintenance process, take into account component aging and beam parameters. Aging components, such as DC bias tip or plasma chamber (Fig.3), does affect the beam. Each 3 months, every source is maintained during dedicated service slots. This sums up to about 100 planned tasks.
Such maintenance may in addition trigger recommisioning in case the change in beam properties is significant.

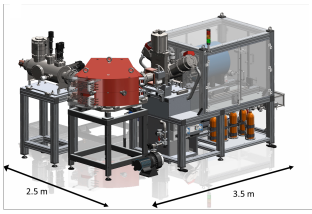


Fig 1: Supernanogan ECR Ion Source layout as used in MedAustron. Three such Ion Sources are used to to enable easy switch between ion species and high uptime during clinical treatment. Sources, which are not in use can be accessed, but to ensure patient safety no activities are allowed in the machine outside of dedicated safety slots.

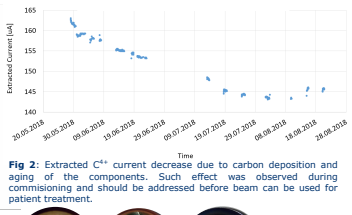


Fig 2: Extracted C^{4+} current decrease due to carbon deposition and aging of the components. Such effect was observed during commisioning and should be addressed before beam can be used for patient treatment.

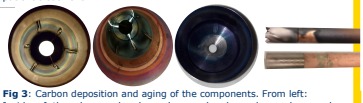


Fig 3: Carbon deposition and aging of the components. From left: Inside of the plasma chamber, plasma chamber, plasma lens and comparison of the used DC bias tip (top) to the new one (bottom)

What level of stability do we need ?

The number of patients MedAustron can treat depends on several factors, such as beam availability (uptime) and intensity.

On one side maximum beam intensity is limited by legal regulations. Taking into account the safety systems reaction time we are not allowed to, even in case of componet failure, exceed certain maximum dose. We identify and test all failure scenarios to take preventive actions.
On the other sid current drop prolongs patient treatment.
On top of this even short violation of required beam parameters interlocks the machine stopping the treatment and causing delays. Therefore, for clinical operation, we must provide very stable beam.

Initially our carbon source was experiencing regular currect drops (Fig.4). Carefull investigation allowed us to find rood cause and increase beam stability significantly.

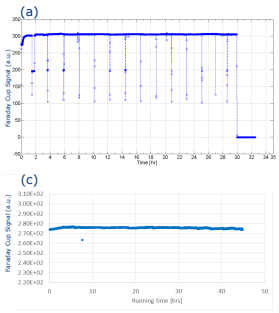


Fig 4: Source stability plots. Initially the source was not clinical-ready as there were current drops on regular interval. Such behaviour would stop clinical operation each time it happened with significant recovery time to continue. This issue was solved during source commisioning.
Panel description:
(a) Source current drop on regular intervals
(b) close up on the drop with a visible step behaviour
(c) source stability monitored after correctly adjusting relieve valve.

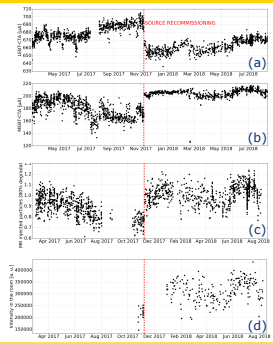
*Source current in mA measured on Faraday Cup with no secondary electron suppresion.

Data aquisition and source recommissioning

Source performance does have an impact on the whole accelerator. We can observe this measuring 'beam QA' each day before patient treatment. It gives us a opportunity to observe processes like radiation damage to detectors, temperature drift effects, aging and impact of the source on the rest of the machine.

Thanks to many iterations of similar measurements even a sub-milimeter beam deviation or slight decrease in the number of particles is visible. Such events trigger planned recomissioning.

The results of such work is presented on the Fig.6
Recommisoning usually includes extensive scan of source parameters (Fig.5, attached emmitance plots).



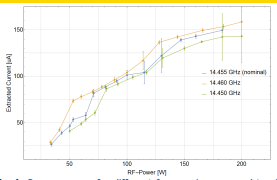
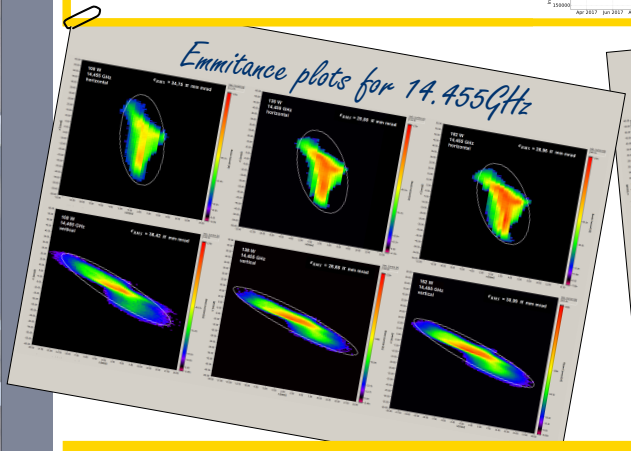
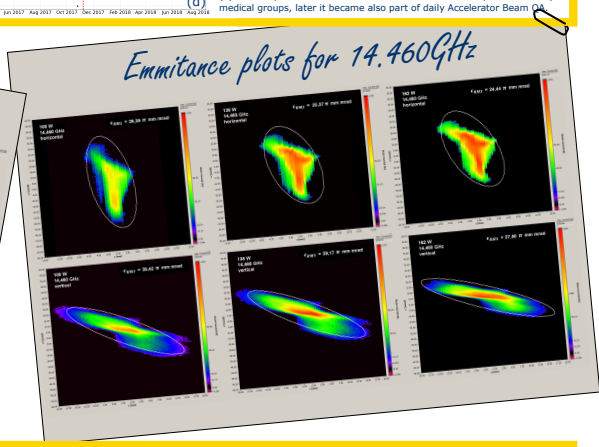


Fig 5 (up): Power sweeps for different frequencies are used to pick up the best frequency in terms of signal to noise ratio and low reflected power. This gives possibility to increase the RF power without changing the other source parameters for the needed intensity into the treating room. (For more information see talk by N.Gambino)
Fig.6 (left): Source recommisioning effect on the machine:
(a) Source current in low energy beamline is lower after the adjustment.
(b) In medium energy beam line we can observe both higher current and significantly better stability
(c) Number of particles injected into the main ring is higher with significant shot-to-shot fluctuation (which is a goal of another investigation)
(d) Intensity in the room. Before Nov-2017 it was only measured by medical groups, later it became also part of daily Accelerator Beam QA





Future plans

Currently our efforts concentrate on Carbon beam comissioning.
This work should be finished in 2019, when we will start patient treatment with carbon ions. This is also when source 2 settings , used for carbon ions, will be fixed.

There is one more source wainting to be commisioned in MedAustron: Source 3. It was planned as backup unit. But can be used to test settings, measure source behaviour or prepare additional beam species.

In addition, thanks to reproducible daily measurements, we will be able to aquire in time large collection of accelerator performance data. With improved tools and better measurements this could provide valuable insight on long term stability, aging effects, reproducibility and maintenance which we want to explore.

Fig 7: MedAustron Ion Therapy Center in Wiener Neustadt. A view on the facility.