

Status of the SmartPhantom and Commissioning at MedAustron

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1 MedAustron

- IR2-H: Carbon
- IR1: Carbon
- Twiss Rematch
- IR1: 800 MeV Proton

2 SmartPhantom

MedAustron Facility

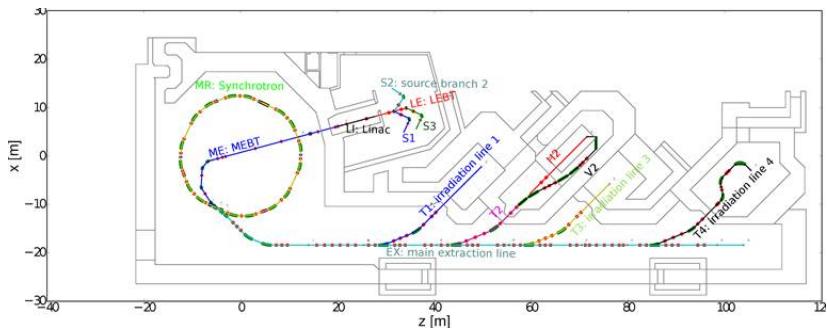


Figure: Simple overview of MedAustron facility, highlighting different sections from the sources to the various rooms.

- MedAustron was designed to deliver both proton and carbon-ions for medical treatment and research.

MedAustron Irradiation Rooms

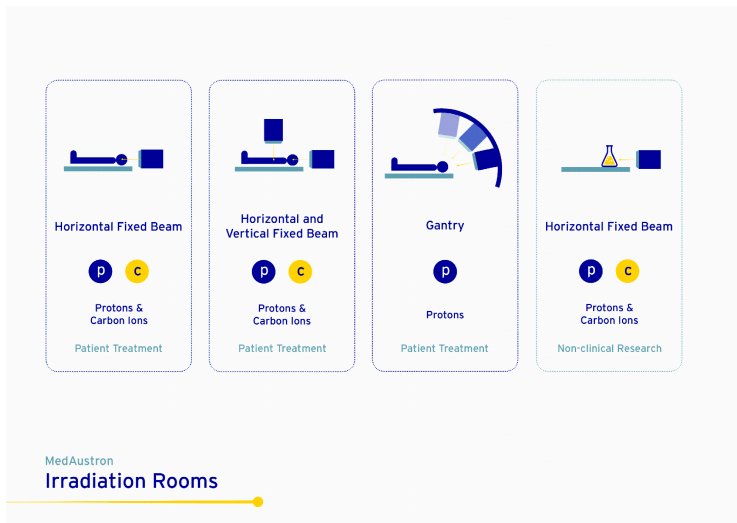


Figure: The four irradiation rooms at MedAustron with one dedicated solely for research, and another not yet fully commissioned.

IR2H - Carbon Spot Size Commissioning

- The carbon-ion beam is delivered in a range of 120 MeV/u to 400 MeV/u.
- The spot size for these energies was to be between 6 mm to 10 mm (In terms of the FWHM), from a position 50 cm upstream of isocenter to the isocenter.
- The beam ellipticity must also remain within $\pm 10\%$.

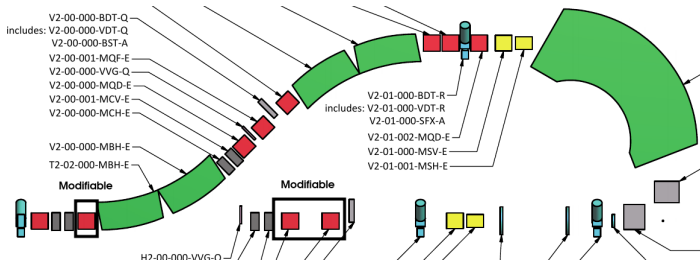
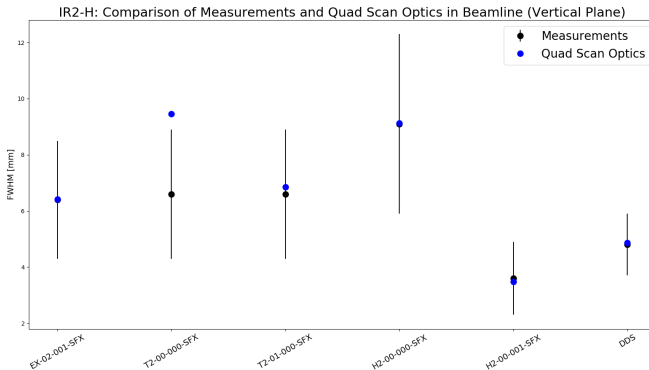


Figure: Simple overview of the horizontal and vertical beamline for IR2.

- Only a limited number of quadrupoles could be modified.

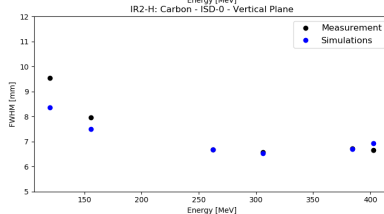
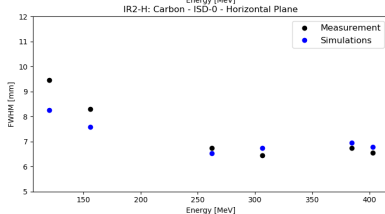
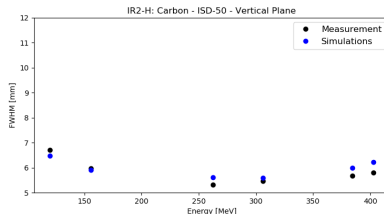
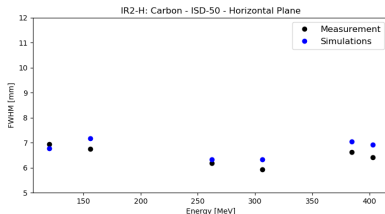
IR2H - Simulating Beam

- Beam time was very limited due to daily medical treatments with protons.
- To make the most of available shifts, it was critical to be able to characterize the beam and simulate it in the beamline.
- A quadrupole scan method enabled the beam to be characterized in the vertical plane:



IR2H - Simulating Beam

- Apparent underscattering in Geant4 simulations (with BDSIM):



- Further investigation revealed to be an issue with modelling the medical nozzle.

IR2H - Spot Size Adjustment

Finer adjustments had to be done on shift through a “trial and error” method.

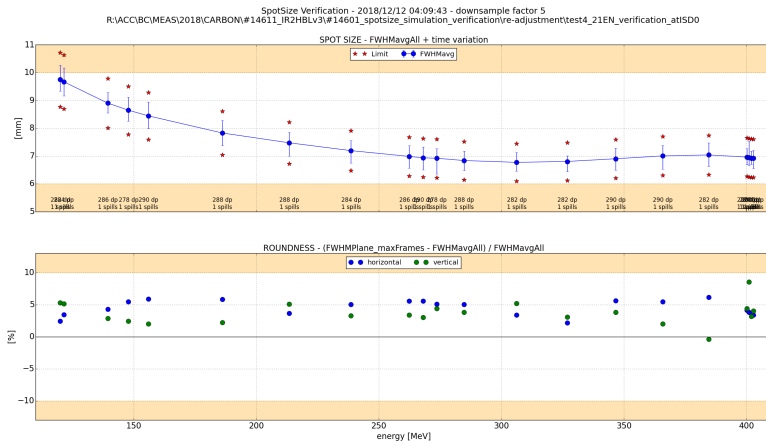
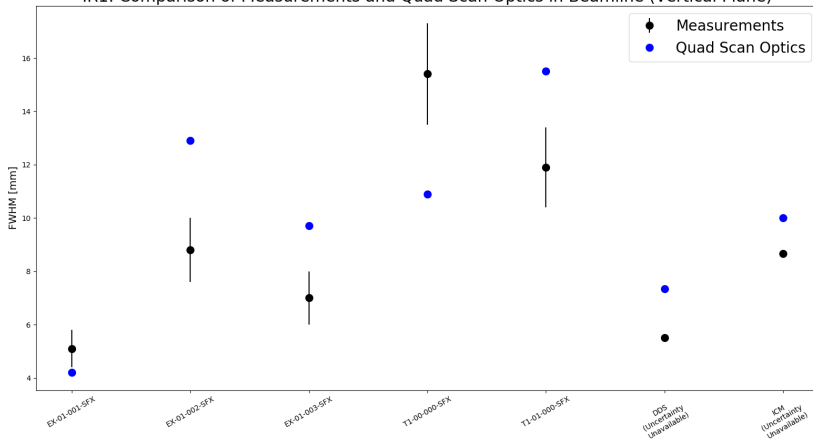


Figure: Top plot is the spot size, and bottom is the beam ellipticity.

IR1 - Carbon Spot Size Commissioning

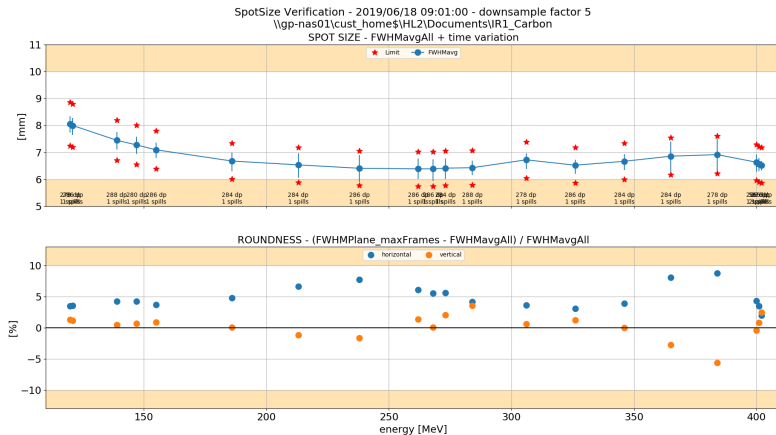
- Similar procedure had to be repeated for the research room, though with the restrictions only at isocenter.
- Previous procedure gave a poor characterization of the beam.

IR1: Comparison of Measurements and Quad Scan Optics in Beamline (Vertical Plane)



IR1 - Carbon Spot Size Commissioning

- The spot size had to be commissioned blindly by “trial and error”.



Twiss Rematch Procedure

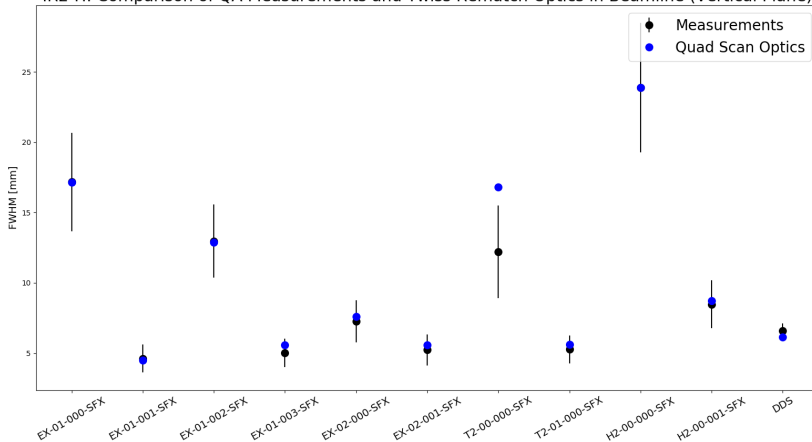
- A new method to characterize the beam was developed through a Twiss Rematch procedure.
- One could try various Gaussian beam configurations and use a minimization procedure to match to trajectory measurements.
- Little to no dedicated beam time required to characterize the beam.
- Relatively quick to find a beam configuration fitting to measurements.

Twiss Rematch against QA Data

- To gauge effectiveness of this new procedure, a comparison of beam profile against QA data taken for 252 MeV protons:
- Initial Twiss Parameters (@EX-01-000-SFX):

$$\beta_y = 23.01[m] \quad \alpha_y = 12.63 \quad \epsilon_y = 2.58 \times 10^{-6}[\pi \cdot m \cdot rad]$$

IR2-H: Comparison of QA Measurements and Twiss Rematch Optics in Beamline (Vertical Plane)

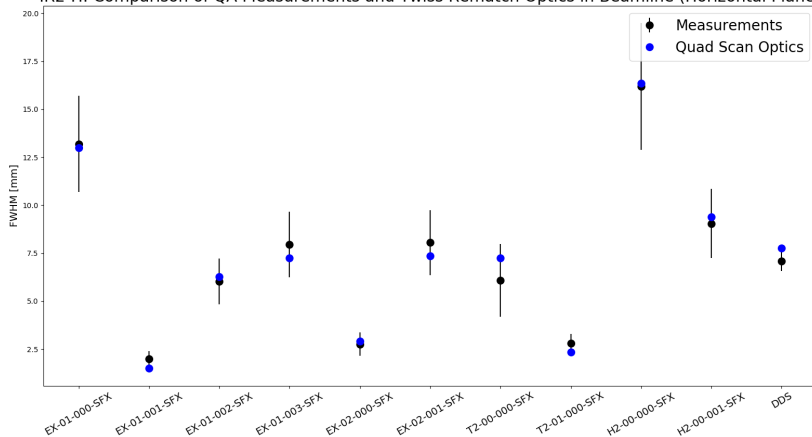


Twiss Rematch against QA Data

- Works for the horizontal plane, but due to the nature of the extract horizontal plane, values can sometimes be extreme.
- Initial Twiss Parameters (@EX-01-000-SFX):

$$\beta_x = 52.25[m] \quad \alpha_x = -30.36 \quad \epsilon_x = 5.21 \times 10^{-7}[\pi \cdot m \cdot rad]$$

IR2-H: Comparison of QA Measurements and Twiss Rematch Optics in Beamline (Horizontal Plane)



IR1 - p800 Spot Size Commissioning

- 800 MeV protons was to be delivered for the research room.
- Three spot size requested: $4.5 \times 4.5 \text{ mm}^2$, $8 \times 8 \text{ mm}^2$, and $20 \times 20 \text{ mm}^2$.
- With the Twiss Rematch method, the three spot sizes were optimized entirely within one shift (<8 hours).
- There are discrepancies due to scattering, but regions to do the fine adjustment could be identified before a shift.

SmartPhantom

SmartPhantom is proposed to be an instrumented phantom:

- Several scintillating fibre stations in series will measure the energy deposited.
- Consists of 250 μm fibres
- A single plane consists of 982 of such fibres, with a station consisting of two planes oriented 90° with each other.
- Infer information both on-line as well as through more detailed off-line analysis.

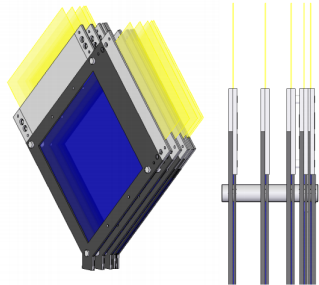
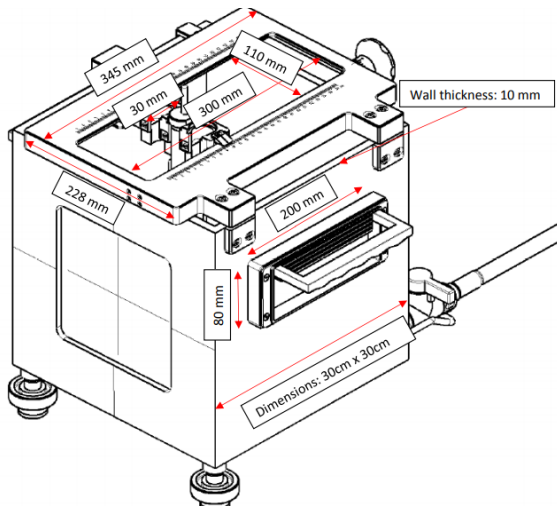


Figure: Not the latest design for the frames.

Water Phantom Dimensions

These planes can then be placed into a water phantom in front of the cells:



Impact of Scintillating Fibres

Effect of the presence of the planes based on Geant4 simulations for protons:

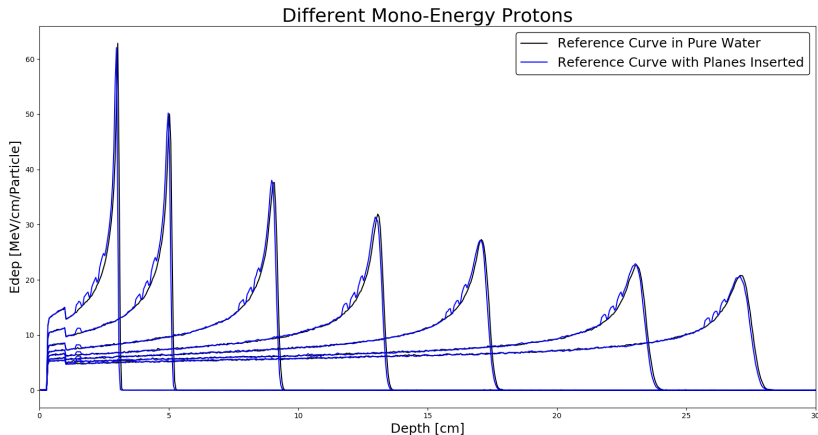


Figure: (Simulation) Comparison of the energy deposition of multiple energies of proton in a pure water phantom (black curve) against the energy deposition with four SmartPhantom stations present (blue curve). The initial bump at the start is due to the walls of the water phantom.

Impact of Scintillating Fibres

For carbon-ions:

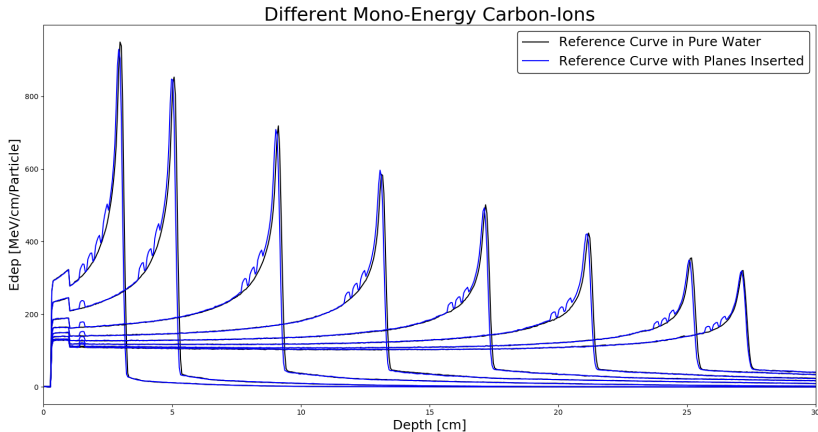


Figure: (Simulation) Comparison of the energy deposition of multiple energies of carbon-ions in a pure water phantom (black curve) against the energy deposition with four SmartPhantom stations present (blue curve). The initial bump at the start is due to the walls of the water phantom.

Readout

- To readout the scintillating fibres, each fibre is connected with a clear fibre.
- The bundle of clear fibres will then be imaged by a camera.
- The controls/triggering for the camera will be controlled with LabVIEW code which is being developed.
 - LabVIEW can provide a GUI for the user.
- Images will be analysed with code in order to get the energy deposition.

Possible Analysis Results

- May be possible to reconstruct the energy deposition curve based on the measurements:

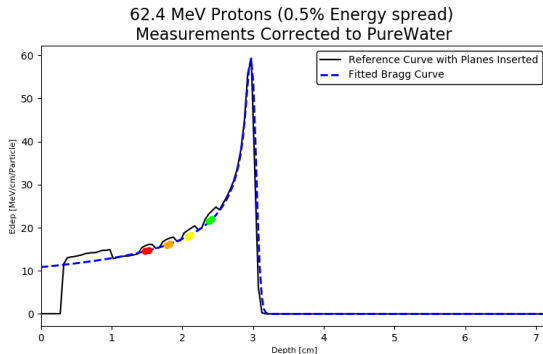


Figure: (Simulation) The black curve is the energy deposition from a simulation (i.e. what one would measure). The coloured points are what is measured. The curve in blue is fitted Bragg peak to the 8 measured points.

Possible Analysis Results

In principle, this should work for all energies: (as well as carbon-ions)

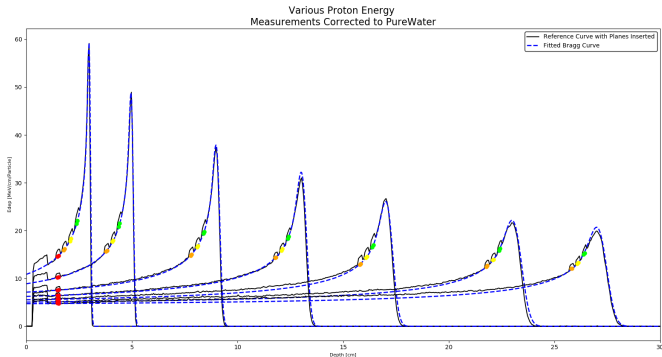


Figure: (Simulation) The black curve is the energy deposition from a simulation (i.e. what one would measure). The coloured points are what is measured. The curves in blue are fitted Bragg peak to the 8 measured points.

Possible Analysis Results

Would also be able to measure the beam profile:

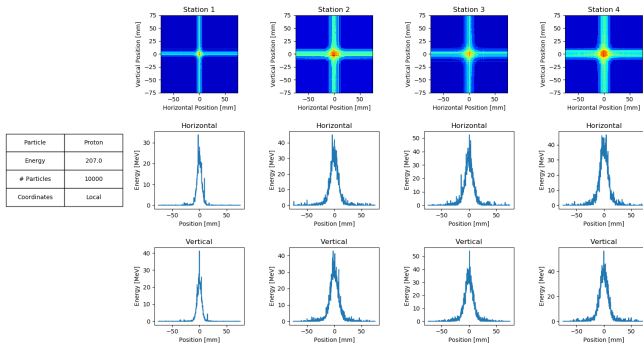


Figure: (Simulation)

Could try to match profiles to simulations to get location of dose deposits in cell samples.

SmartPhantom Schedule

- It is expected that the assembly of the jig will be finished near the end of August.
- In parallel, code for the readout of the clear fibres from cameras will be developed combined with various analysis codes.
- Manufacture and prototyping of the detector planes using a collimated Sr-90 source will take place from the end of August to early October.
- These detector planes will then be brought to MedAustron to be used in shifts taking place from October onwards.

Thanks for Listening!