

## THE HEAVY ION GANTRY OF THE HICAT FACILITY

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### Abstract

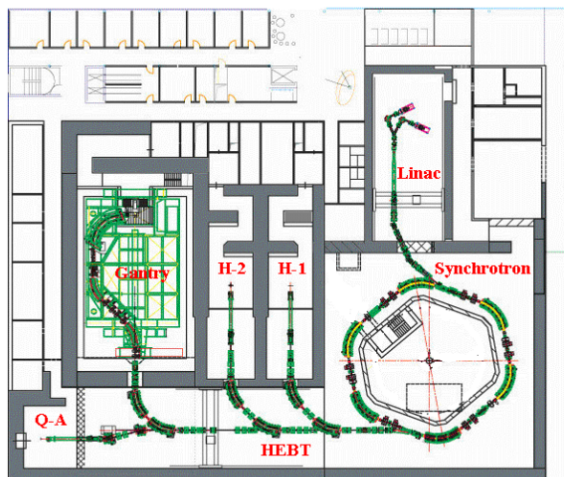
The Heavy Ion Cancer Therapy Project HICAT at the University Hospital of Heidelberg is under construction. One unique feature of the treatment facility is the first heavy ion gantry in the world. The gantry will allow the patient treatment with different ion species up to 430 MeV/u and full geometrical flexibility. This functionality has to be maintained for up to 300 000 rotations over the envisaged life cycle of 15 years. The order for the delivery of the supporting structure as well as the integration of the main components was given to MAN Technologie. GSI had taken the responsibility to coordinate all component suppliers and to commission the system until reliable beam conditions are reached. This paper reports on challenging construction items like the interface to the building, the position stability and the patient environment.

### INTRODUCTION

The construction of the dedicated cancer therapy facility in Heidelberg has started [1].

The key parameters of the facility will be the following:

- treatment with low and high LET-ions
- relatively fast change of ion species
- 3 treatment areas for up to 1000 patients per year
- integration of an isocentric gantry
- main ion-species: p, He, C, O
- ion-range in water: 20 -300 mm
- ion-energy: 50 -430 MeV/u
- extraction-time: 1 – 10 s
- beam-diameter: 4 – 10 mm FWHM
- ions/spill:  $1 \cdot 10^6$  to  $4 \cdot 10^{10}$

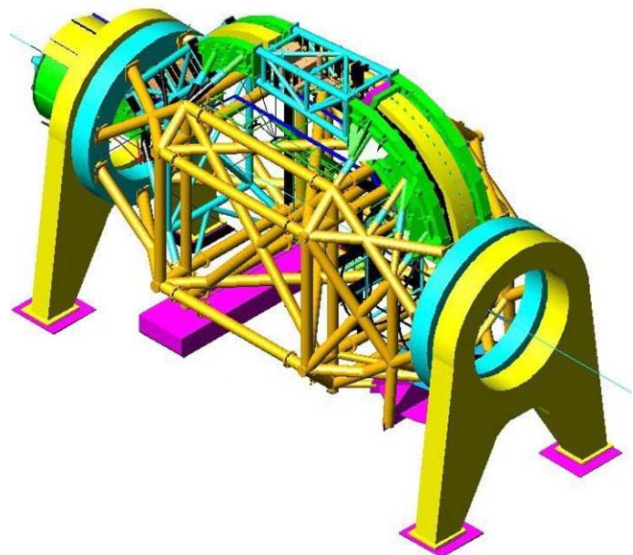


**Figure 1:** Layout of the first underground floor housing the accelerator complex

Figure 1 shows the layout of the first underground floor of this facility with the accelerator sections and the treatment places. The accelerator chain consists of an injector linac, accelerating the ions to an energy of up to 7 MeV/u, followed by a compact synchrotron with a circumference of about 65 m. The beam is distributed by the high energy beam transport line HEBT to the four beam stations. Station one and two are fixed horizontal beam stations for patient treatment. In station three the beam is guided along an isocentric gantry allowing irradiation from all directions. The fixed beam station number four will be used for quality assurance, development and research activities. All places will be equipped with rasterscan treatment equipment for a full 3D volume conformal irradiation.

### THE HEAVY ION GANTRY

In order to have full geometrical flexibility of the entrance channel of the beam into the patient a gantry will be built which will be able to transport protons and light ions up to oxygen with energies corresponding to a penetration depth in tissue between 20 and 300 mm.



**Figure 2:** Overview of the isocentric ion gantry

Intensive discussions led to an isocentric gantry design with the integration of the rasterscan components. Together with other components such as vacuum chambers and treatment monitor devices the following beam transport elements are included:

- One 90°-dipole (D3)
- Two 45°-dipoles (D1, D2)
- Eight quadrupoles (Q1 – Q8)
- Two scanner magnets (SCV, SCH)
- Two steerer magnets (STH, STV)
- Two diagnostic chambers (DC1, DC2)

In order to reduce the uncertainties of this progressive approach several tests with beam in a fixed station set up have been performed [2]. It was proven that the scanning through the 90°-dipol will be feasible without changes to the treatment method.

In July 2003 the order was placed to the company MAN Technologie for the construction of the structure and the integration of the components. Since then intensive investigations and discussions have taken place to push the design towards construction feasibility. Main issues until now have been

- the links to the building
- the position and angular stability of the beam transport components under different gantry angles
- the compliance with medical legislation with respect to mechanical stability
- the integration of the beam transport components into the supporting structure during the assembly process
- the patient environment

### BUILDING ASPECTS

Because of the size and weight of the gantry, its integration into the building is a challenging issue. Assembly complications arise from the fact that the volume of the gantry room is minimized to reduce building costs.



**Figure 3:** Preparation work for the gantry floor (06/04)

Being in itself a complex system the assembly and commissioning of the gantry will take time. The

ambitious overall time table of the project therefore imposes commissioning with beam up to first two treatment places while the gantry room is still accessible.

**Table 1:** Milestones of the Isocentric Ion Gantry

Placing of Order	07/2003
Delivery to Heidelberg	08/2005
Assembly finished	06/2006
Commissioning finished	06/2007
Facility fully operational	12/2007

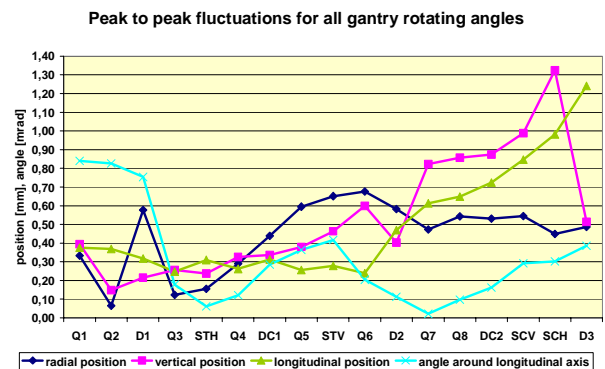
### BEAM STABILITY

The 3D volume conformal rasterscan method requires reproducible beam positions for all gantry angles. Given the weight of the components to be integrated it was necessary to perform extensive FEM – calculations to optimise the supporting structure to the required stiffness without increasing too much the total weight of the system.

**Table 2:** Weight and length of the gantry system

weight of beam transport components	135 to
total weight of rotating part	570 to
total weight of the system	630 to
diameter of rotating part	14 m
length of rotating part	19 m
overall length	22 m

Finally a solution was reached which satisfies the individual requirements for position and angular stability of the relevant beam guidance components.



**Figure 4:** peak to peak fluctuations of beam guidance components

In Figure 4 the calculated peak to peak fluctuations of the beam guidance components under all gantry angles with respect to the optimum position are shown. Since the

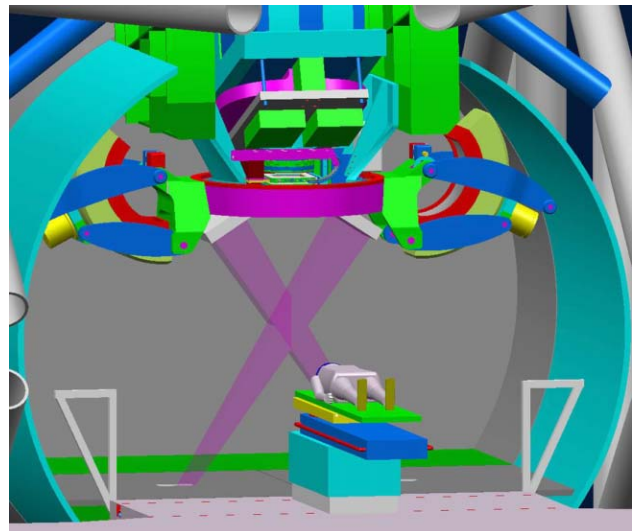
beam position deviations resulting from this movement will be different for different gantry angles the orbit correction scheme will also be gantry angle specific. In order to guarantee the reliability of the system, all these deviations have to be reproducible and therefore only elastic deformations are allowed. The security factors for the design were chosen in such a manner that more than the predicted three hundred thousand turns of the gantry over its envisaged life time can be done in an elastic manner. This design also assures the compliance to the medical law requirements with respect to mechanical stability.

### PATIENT ENVIRONMENT

The part of the gantry which is close to the patient requires special design effort:

- There is a dense package of accelerator and treatment components in this area.
- Two x-ray tubes and a PET-option have to be integrated in the rotating part.
- The diameter and the layout of the gantry will not allow a fixed floor closer than 1.4 m distance to the isocenter.
- The isocenter will be more than 7 m above the floor level of the gantry room and more than 5 m away from a wall – so the realisation of a precise and reliable supporting structure for the patient has to be carefully designed.

A study was carried out which yields as a result a solution for the integration of the PET-camera while still allowing a maximum of geometrical flexibility and mechanical stability. It will also be possible to use the x-Ray tubes for all gantry angle positions.



**Figure 5:** A possible patient environment including PET and X-Ray tubes in the rotational part

A second study was performed which came up with a solution for the supporting structure of the patient. This structure will be fixed at the concrete wall of the gantry room. The necessary reinforcements to be foreseen in the wall were also derived from the study.

### REFERENCES

- [1] H. Eickhoff et al., The German Hospital-Based Light Ion Cancer Therapy Project, Presentation FRYACCH01 at this conference
- [2] H. Eickhoff et al., Tests of a light ion gantry section as an example of preparations for the therapy facility, EPAC 2002