SpotOn+

Center for Proton Therapy :: Paul Scherrer Institut :: #15_8/2018

Dear Reader,

it is my distinct pleasure to present you the August edition of our newsletter.
On July 16th, a patient from the University Hospital of Zurich (USZ) was treated in our new Gantry 3 at the Center for Proton Therapy in the framework of a collaborative agreement with this hospital. This has been a four year project, including but not limited to the call for procurement, WTO process, negotiations with the vendor, construction and finally commissioning of this treatment unit, which I had the privilege to steer with the help of Drs. Jürgen Duppich and Alexander Koschik, the two sequential project leaders of this venture. This rather long process is nicely summarized in the article written by Mrs S. Goldhahn and included in this newsletter. One of the major endeavors was to integrate Gantry 3, a commercial product, into the complex systems and IT architecture of PSI. Not an easy task but one of paramount importance, as control and safety systems are the brain and 'safety net' of our medical devices delivering proton radiation to our cancer patients. The integration of the Patient Safety System (PaSS) was led by Dr. Martin Grossmann and my colleague gives a short summary of his tasks to achieve an optimal interface between a commercial system and PSI's existing systems. Thanks to him and my colleague Dr. Christian Bula, who was responsible for the integration/connection of the control systems, and their respective teams, this first patient was successfully and safely treated at PSI. The last article pertains to the commissioning of patients treated at Gantry 3 using a laser tracker. Many thanks go also to Dr. Sairos Safai and his team for commissioning our new Gantry. Unlike with Gantry 1 and 2 where patients are imaged before the delivery of the radiation fraction outside and inside the room, respectively, patients treated on our newest medical unit are aligned at isocenter using on board imaging devices. The commissioning process showed that the accuracy allowed us to treat very precisely our patients.
That said, stay tuned for our next edition of SpotOn+ for some additional info on our treatment program at PSI.

Yours sincerely,
Prof. Damien Charles Weber,
Chairman of CPT
Paul Scherrer Institute

General

A new treatment facility came into operation

Installation of Gantry 3: a) shows the end of the beamline, the coupling point to the Gantry and the Gantry corpus from behind in the machine room; b) shows the (future) treatment room without any wall cladding; c) shows the final treatment room with the patient couch in front and the beam head (called nozzle) on top, from which the proton beam emerges.

With millimetre precision, certain tumours can be irradiated at the Paul Scherrer Institute PSI using protons. Now PSI, where more than 8,000 patients have already been irradiated successfully, has expanded its capacity through a joint project with the University Hospital Zurich and the University of Zurich, with a state-of-the-art treatment facility: the new Gantry 3.

After four years of planning and construction as well as a one-year test phase, the time has come: The most modern irradiation facility at the Centre for Proton Therapy CPT of the Paul Scherrer Institute PSI has been put into operation. With a total weight of 270 tons and a diameter of 10.5 metres, Gantry 3 is the largest machine installed to date at CPT. The main benefit the collaborators cite with the arrival of Gantry 3 is shorter waiting times for patients with cancer. Damien Weber, head and chairman of CPT, emphasises: “With Gantry 3, we can offer highly effective proton therapy to more patients than ever before, because we have more capacity. That will be especially beneficial for children, for whom a conventional cancer irradiation would be too risky. With the proton therapy, we irradiate the tumour more accurately and better protect the healthy tissue around it.”

The good cooperation and the tight exchange between PSI and the University Hospital Zurich, as well as all other Swiss university hospitals and specialised clinics in Aarau, Lucerne, and St. Gallen, have contributed decisively to this success, according to Weber. Each cancer patient receives an individual, personally tailored treatment plan. This can also include other forms of treatment, such as operations or chemotherapy, in addition to proton therapy.

Proton therapy with the spot scanning technique means that a beam of positively charged atomic particles is fired at a tumour, and that the beam scans this tumour from back to front, layer by layer and row by row – until the proton beam has hit every spot on the tumour. Some types of cancer grow around sensitive structures in the body, such as the optic nerve for example, or have a very irregular form. “If these tumours are treated with conventional radiation therapy, a much too large area has to be irradiated in order to really hit the whole tumour”, Weber explains. It is precisely with these complicated tumours that the special advantage of proton therapy comes into play: Only with a proton beam can the doctors control how deep in the body the particles should exert their maximum effect. Up to that point they do in fact penetrate other tissues, yet they do very limited damage there. The tissues behind the tumour remain unscathed. Consequently, there are fewer side-effects from proton irradiation than with conventional radiation therapy.

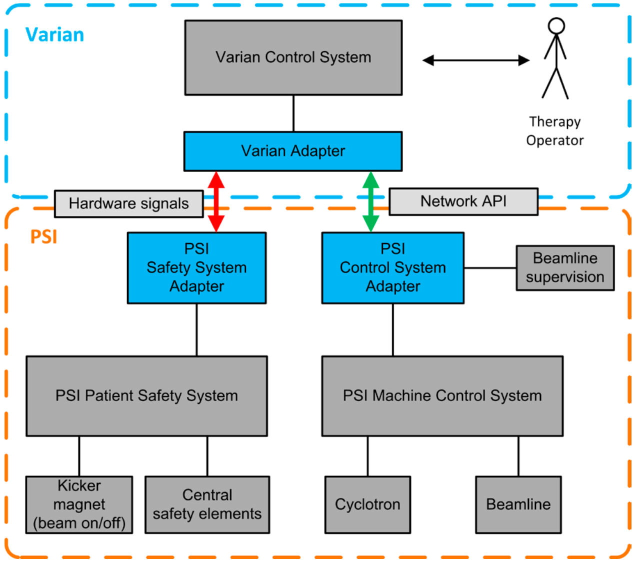
The new machine immediately breaks several records at CPT. Not only is it the largest of the three gantries, but it was also installed in the shortest time to date. “To build an irradiation facility like this gantry was a big challenge”, says Damien Weber. “It was only possible thanks to the outstanding collaboration with our Swiss industry partners as well as the support of various departments of PSI. Through joint efforts, we have installed cutting-edge technology here for cancer patients.” Gantry 3 was financed with money from the lottery of the canton of Zurich as well as PSI’s own funds. The new treatment facility was opened in May with a ceremony in which representatives from science, politics and industry took part.

The first patient treated at Gantry 3 is a 40-year old Swiss female patient presenting with a benigne brain tumor. She was operated at University Hospital Zurich and was recommended proton therapy due to her young age and localization of the tumor. Her irradiation sessions at Gantry 3 went smoothly and safely.

Excerpt from a press release written by Sabine Goldhahn

Physics News

Integration of Gantry 3 Controls and Safety Systems



Principle for the Varian/PSI Control and Safety System Integration. Varian's and PSI's control system are left untouched. Dedicated adapters serve as interface between the two worlds. Control signals are passed over the network whereas safety critical signals are connected by hardware lines.

Gantry 3 is based on Varian's commercial ProBeam® product. As such it comes fully equipped with its own systems to apply the proton beam in a precise and safe way. The situation of Gantry 3 is however different to ProBeam®: in the standard system the whole facility is provided by Varian. But for Gantry 3 the accelerator and the beamline, along with their respective control and safety systems, have been developed by PSI or third parties. The challenge was to connect these worlds and the different technologies involved.

The hardware of the PSI Safety System Adapter installed in the Gantry 3 electronics room. The upper crate holds the two redundant IFC1210® controllers. In the central part of the rack are two Signal Converter Boxes (SCB) that provide connections to external signals from Varian and from PSI. Communication between the IFC210 and the SCBs is handled over fibre optical links (orange cables). The lower part of the rack holds the patch panel with connections to PSI's central safety systems.

The approach to solve this problem was to leave the existing systems mostly untouched and provide interfaces by newly developed interfaces called "adapters". Two kinds of connections can be distinguished:

First, commands concerning the configuration of accelerator and beamlines (e.g. setting of beam energy and intensity, open/close of beam blockers etc.) are handled through a network interface. The PSI Control System Adapter relays these commands to the PSI Machine Control System which then configures cyclotron and beamline accordingly. A supervision of the correct setting of the energy selection system is also implemented in the PSI Control System Adapter.

The implementation is based on the platform for PSI's Therapy Control Systems which allowed the reuse of large parts of the software. Most of the hardware is the same as used elsewhere at PSI which allows the pooling of spare parts.

The second kind of connection are the fast control commands (normal beam on/off) and signals concerning the safety systems (interlocks etc.) which are transmitted by hardware lines of various types. While reusing much of the technology from PSI's existing safety systems, like redundant cabling to allow the detection of broken lines, it was decided to program the logic on a state-of-the-art platform. The choice was the IFC1210® controller (developed jointly by company IOXOS and PSI) which features a user programmable Virtex 6 FPGA chip. It contains the safety logic which after system startup is totally autonomous.

The PSI Safety System Adapter passes a total of 116 safety signals back and forth between Varian and the PSI Patient Safety System. It also handles the conversion of the various signal types (different electrical and optical connections): two Signal Converter Boxes (SCB) accept different types of electrical and optical connections and link them to the IFC1210® controller via fibre optical cables.

The PSI Safety System Adapter is responsible for passing on interlock signals to the central safety systems. Therefore it has been designed failsafe in the sense that a broken connection or a power failure will always put the system in the safe state (no beam). In addition it has been implemented redundantly i.e. the adapter physically exists in two instances which are constantly checked for consistency. Again, in case of inconsistency, the system will go to the safe state.

Both the Control and the Safety Adapter have been implemented according to CPT's development process which includes thorough unit and system testing. They have been installed in 2015 and have been successfully running through the commissioning phase of Gantry 3.

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Medical-Physics News

Commissioning of a commercial patient positioning system of the ProBeam Gantry 3 using a laser tracker

Introduction: For accurate radiotherapy, a reliable patient positioning system ensuring daily reproducible positioning is crucial. Hereafter the expression “patient positioning system” refers to the mechanical components of the system, also referred to as “table”, and not to the software for patient alignment. For such a system, not only translational point-to-point moves, but also rotations around the isocenter need to be accurate and reproducible. This should be the case regardless of treatment localisation and patient weight. Ideally, after patient alignment at a reference imaging position, the table should allow reaching the actual treatment position for the first, and all subsequent fields, without the need to re-image between such fields by means of precise and accurate table motions (e.g table isocentric rotations). A reliable system with these characteristics optimizes the amount of x-ray images to be taken during patient alignment and verification, which in turn reduces the treatment time and ultimately improves patient throughput and satisfies the ALARA principle.

The Center of Proton Therapy (CPT) at PSI has been operating in this manner since the start of patient treatments in the 90’s, first with Gantry 1 and then with Gantry 2. The patient is imaged only once at the beginning of each fraction: in Gantry 1 with a CT positioned outside the treatment room, and in Gantry 2 with a CT-on-rails located in the actual room.

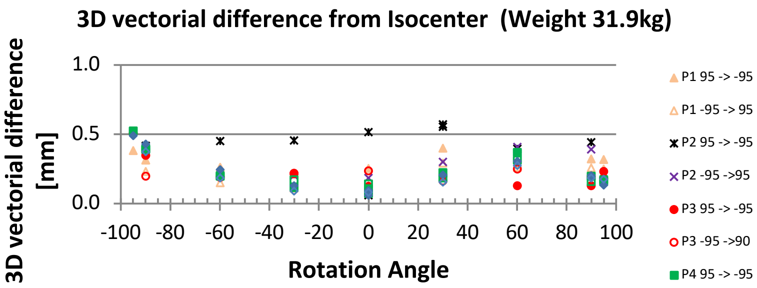

Figure 1: Results for patient table isocentric rotations for a weight distribution of 31.9 kg. The rotation range of motion is from -95° to 95°. 95 -> -95 refers to clockwise rotations and -95 -> 95 refers to counter clockwise rotations.

On the newly commissioned Varian ProBeam Gantry (Gantry 3) patient alignment is performed at isocenter with the on-board X-ray imaging units. The patient positioning system consists of a 6 degree of freedom KUKA robot with a QFix KVue couch mounted on top and the mechanical control system. In the following we present a method to characterize this table using a laser tracker (LT), which guarantees an accuracy of measurement up to 30µm.

Methods: Three realistic human body weight distributions (~ 40kg, 135kg and 150kg) and up to 5 target points (P1 to P5) within the treatment volume (head, shoulder, sternum, right and left hips) are measured. Each target point is individually aligned at isocenter using the laser tracker at the reference imaging position (at table rotation angle 0.0°). Target setup error is ‹0.1mm. Translational motions, isocentric table rotations and pitch and roll rotations are then executed and final target position recorded with the laser tracker. 3D distances from nominal isocentre for each weight and target in the presence of (i) isocentric rotations (every 30°) with and without 1°pitch and 1°roll, as well as accuracy of (ii) pitch and roll and (iii) small (‹1cm) and large (›1cm) point-to-point moves were determined as well as repeatability and the influence of a 20cm center-of-mass shift at 135kg for (i).

Results: 3D residual distance is below 1mm (range 0.03mm – 0.67mm) for all angles, weight classes and targets during isocentric rotations (e.g. Fig. 1), even with pitch and roll. Repeatability of average deviations in (i) over 3 months, and shifting the center-of-mass further from the last KUKA joint can introduce up to 0.5mm deviation. Maximum deviation between nominal and measured pitch and roll is 0.03˚at 151.2kg. While the direction of rotation has no influence, the distance from the last joint of the KUKA robot can be challenging. Overall, the accuracy of the table is satisfactory, as image guidance would not be able to detect deviations in patient position ‹0.5mm.

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Villigen PSI, August 2018