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DATA SUPPLY OF ACCELERATOR DEVICES – DATA MANAGEMENT OF DEVICE PROCESS DATA AT A MEDICAL ACCELERATOR

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Abstract

HIT is the first dedicated proton and carbon cancer therapy facility in Europe. It uses the full 3D intensity controlled raster scanning dose delivery method of pencil beams with ion beams of 48 - 430 MeV/u provided by a linac-synchrotron-system.

Ion beams in this wide range of energies, different beam sizes, and intensities have to be provided by the control system to all treatment rooms at any time with high accuracy, stability, and reproducibility. This paper briefly reflects some aspects of the data supply, i. e. the settings of accelerator devices at a medical accelerator. This includes the generation of control data, storage, and data recovery routines, which have been developed at HIT in the recent years.

That is in particular the management of verified therapy data and settings, which are stored in a non-volatile memory of the device controllers, and – as a backup – in a database and which are protected against unintended changes for safety reasons.

INTRODUCTION

Cancer therapy with carbon ion and proton beams has been carried out at the Heidelberg Ion-Beam Therapy Center (HIT) since 2009. HIT uses the intensity controlled raster scanning method of pencil beams as dose delivery system. The accelerator is based on a linac-synchrotron system accelerating ions to energies up to 430 MeV/u. Protons, carbon, oxygen, and helium ions are slowly extracted by the transverse knock-out extraction method. The facility is equipped with two fixed horizontal beam lines and a rotating beam line (heavy ion gantry) for patient treatment, and an experimental area for research (Fig. 1).

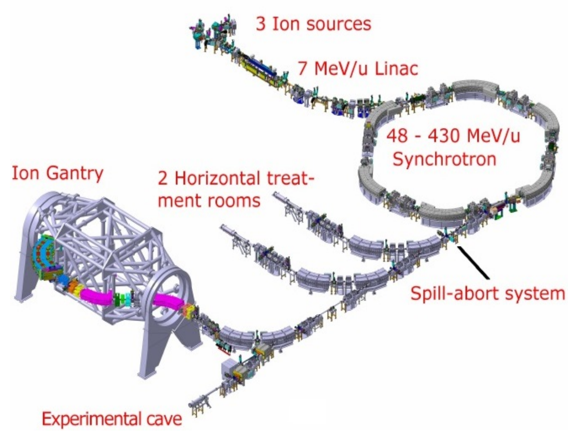

Figure 1: The HIT accelerator: a linac-synchrotron based system delivering 4 ion types to 3 treatment rooms and one experimental area.

Each combination of one of three ion sources and one of five beam targets is represented as virtual accelerator within the accelerator control system (ACS) with associated device groups and set values (accelerator model). Ion beams may be requested from the list of ion beam characteristics consisting of 4 ion types (M), 255 discrete energy steps (E), 4 beam sizes (F), 10 intensity levels (I), and – in case of the gantry – 36 angle steps. These combinations are given the name MEFI combinations. Ion beams of different EFI have to be provided to all treatment rooms at any time. Thus there is a huge amount of different accelerator settings and device data which have to be carefully managed.

Motivated by the rapid increase of device data due to the commissioning of helium and oxygen beams, the installation of a third low energy beam line, and in especially due to the operational experience gained during commissioning of the gantry with its different device settings according to different angle positions, major modifications of the data generation/supply became inevitable by extending and improving the previously limited functions of the control system's data supply applications.

A major concern was to attain a simplified data generation and data management in general which is more adapted to the workflow from beam setting via pre-clinical testing to the clinical use of the ion beams and thus avoiding operational errors.

DATA SUPPLY

The device settings, i. e. the control data are calculated from physical input parameters by the data supply module (DSM, part of the ACS) according to the accelerator model. In order to minimize the commissioning effort only a small subset of input parameters is determined as interpolation points; i. e. for a few energy steps (ca. 10), foci (4), and gantry angles (ca. 10). Residual physical (input) data are calculated by means of a polynomial fit between these points [1–3].

The device settings of the whole MEFI range are stored as binary large objects (blobs) in the device controller units (DCU) and are backed up in a database. There are three different types of blobs, related to different operation modes for commissioning and adjustment, quality assurance, and therapy, the two most important of which as follows [4–6]:

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- Therapy data are stored in the non-volatile memory ("Flash") of the controllers after approval for therapy. This data is well protected from unintended change and can be changed only in a special operational mode. Therapy is using these data while beam requests from the ACS are possible for quality assurance procedures.
- Experimental/adjustment data are stored in the volatile memory of the controllers ("RAM"). These data are used for accelerator adjustment and do not affect the therapy data sets at all allowing for beam adjustment while preserving the verified therapy settings.

Data integrity of the settings is always assured by comparison of the blobs' checksums stored in the device controllers and the database upon every beam request (being aborted in case of a mismatch); changes of therapy data are instantaneously notified by the therapy control system and have to be confirmed by the medical physicists personnel which is in charge of the final therapy beam approval.

Calculation of Gantry Device Set Values

Once the physical input parameters are set and residual physical input data are created by means of interpolation the set values will be calculated out of these polynomial spline values by the data supply module upon user request. A major add-on to the existing DSM is the possibility of selecting different gantry angles or angle ranges that have to be calculated instead of calculating set values over the full gantry angle range of 360°.

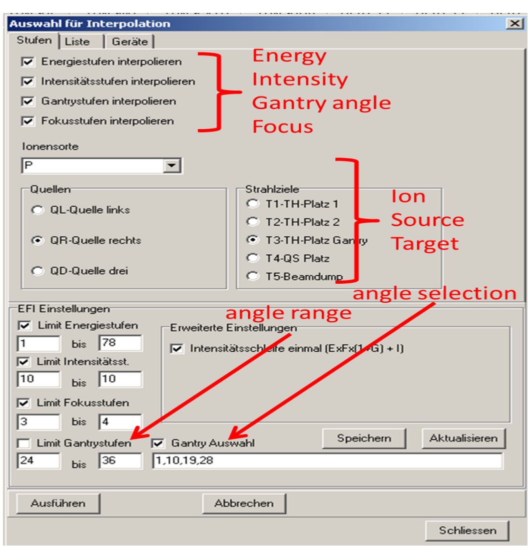

Figure 2: Set value calculation's selection widget: selection of parameter to be calculated; selection of ion type, source, and target; limits and ranges for energy, intensity, beam size, and gantry angle.

By this, only the requested selection of set values will be altered while preserving the verified device settings of other angles or angle ranges and thus minimizing the risk of unintended change of set values. And, secondly, by calculating only a subset of this huge amount of MEFI combinations, the entire procedure became extraordinary time saving. The same applies to the energy-intensity-focus steps, the ranges of which might be selected (see Fig. 2). Once created, the set values may be downloaded to selected devices (see next section).

Download from the Database to the Device Controllers

Concerning the data download from the database to the device controllers most attention was drawn to ease of operation, clear arrangements, and data integrity. The previous functions were restricted to either downloading the device data to all devices or to single devices only. Several improvements to GUIs and applications have been implemented to simplify the download operation, to avoid user mistakes and operating errors. One of the most important improvements is a selection widget (and underlying application) which enables the user to arbitrarily select devices or groups of devices whose data need to be downloaded (see Fig. 3) [7].

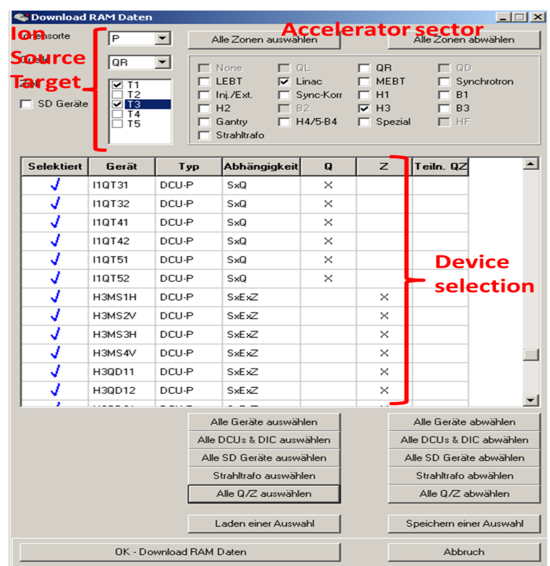

Figure 3: Download selection widget.

In addition the application concludes with automatic checks of the data integrity (comparison of checksums in the device controllers and database). Previously, these checks were carried out by user request only.

Generation of Therapy Data ("Flash")

Once the beam quality was verified using accelerator settings from RAM data, this data might be copied to the flash memory of controllers and database (creation of therapy settings/data as part of the workflow from beam setting to verified therapy settings). Though this procedure has been safe, quality assured and functional in general in the past, the functionality was limited to data generation for all devices or for single devices only. The functionality has been extended in some ways. Firstly by implementing a selection widget and an underlying "flash" application (s. above). So the selection of ion type, ion source, target – if necessary – accelerator sector (such as LEBT, Linac, etc.), and groups

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of devices became more comfortable, clearly arranged and therefore avoiding faulty operation by eventually missing devices whose data had to be changed [7].

Secondly, a key novel feature is the limitation of the therapy data supply to selected gantry angles or ranges of those which is a consequence of patient treatment requirements, as treatment beam plans make use of fixed gantry angles, but different beam energies. Consequently, new therapy settings are created only for preselected angles or ranges of angles while leaving verified device data untouched for others, thus minimising alterations of therapy data settings, and, moreover, minimising the subsequent quality assurance efforts (see Fig. 4).

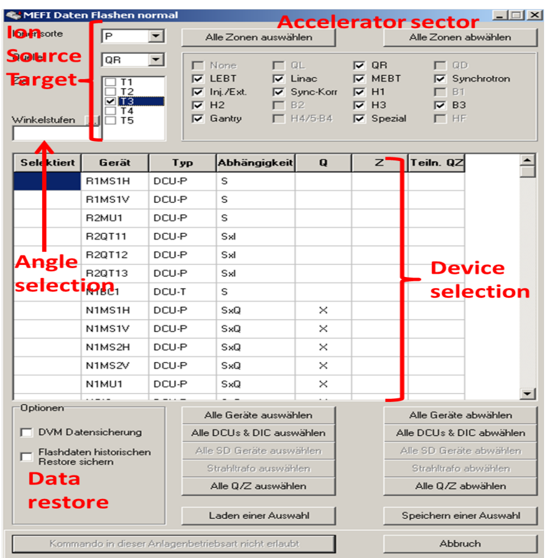

Figure 4: Flash selection widget.

Like in the case of a download, the application automatically checks the data integrity which is a necessary precondition for a cycle execution. Just like in the case of a download, these checks were previously carried out by user request only.

Restoring Therapy Data / Disaster Recovery

Naturally, there are several automatic mechanisms of data backup and data archiving acting on different time scales (on an approximately 15 minutes scale to a yearly basis) and storage media (from network drives to tape archives). Theses backups might be used for data recovery in the case of corrupt therapy data or in the most unlikely event of a data disaster, but only by control system and database experts. Additionally, some of these recovery procedures are time consuming. The novel applications are operator's tools for an easy and faster way of restoring device settings without deeper knowledge of databases by introducing "undo flash", backup, and restore functions to the control system, which have not been implemented from the very beginning. While generating therapy data a copy of the existing data will be written to the database which might be restored easily by a single command within a GUI (see Fig. 5) [7].

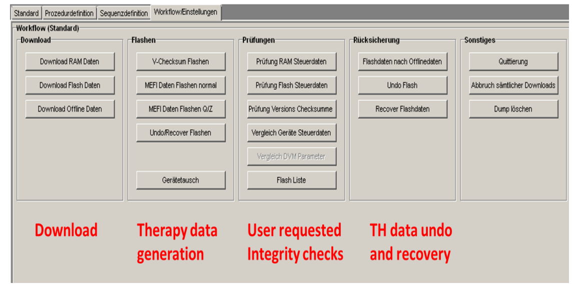

Figure 5: Single command ("One button") Undo/Recovery application together with download, therapy data generation, and integrity check commands.

These data tables will be overwritten with every flash command, but can be saved as a file for possible recovery. Thus with this it is possible to restore the therapy device settings from different dates with a single command.

SUMMARY

The operational experience and optimisation of workflows at the HIT medical accelerator are giving rise to steady extensions to and improvements of the overall accelerator control system and – as part of it – the data supply applications and GUI. Though these applications have been functional and safe from the very beginning its restricted functions needed major modifications in terms of new functions (data interpolation, downloads, therapy data generation, and data recovery) simplification, clear arrangements and generally better adaption to the workflow from beam setting to the clinical use of the ion beams.

These modifications have been developed by HIT and successfully coded and implemented by HIT's industrial partner according to the specifications given.

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