MONOLITHIC DAQ SYSTEM FOR BEAM DIAGNOSTICS AT THE HIT MEDICAL ACCELERATOR FACILITY

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Abstract

The Heidelberg Ion Therapy center HIT is presently in the final phase of commissioning. HIT consists of a two-stage linac followed by a compact heavy-ion synchrotron. The ion beam can be delivered to two horizontal treatment places and a gantry structure for 360° patient treatment. In this contribution we report on the basic concepts for the integration of the beam diagnostic data acquisition into the overall accelerator control system. The equipment-side abstraction layer of facility-wide device classes and its seamless integration besides device control units, e.g. for power supplies, is presented and first operational experiences of the machine commissioning are discussed. As examples for the data acquisition the detection of beam profiles using profile grids, multi-wire proportional chambers (MWPC) and scintillation screens is presented.

INTRODUCTION

Based on a GSI pilot project, where more than 400 cancer patients have been successfully treated using the intensity controlled rasterscan method with carbon ions, it was decided to build a dedicated accelerator facility for medical treatment at the university hospital of Heidelberg. GSI was responsible for the layout of the facility, the procurement of all accelerator parts with industrial partners, as well as the installation and commissioning of the facility. The HIT medical accelerator is presently in the final commissioning stage and consists of two ECR ion sources, a two-stage RFQ/IH-DTL injector linac (7 MeV/u), a compact synchrotron (magnetic rigidity 0.38-6.6 Tm), 2 horizontal treatment places, 1 heavy ion Gantry for 360 degree patient treatment and 1 quality assurance place for tests and experiments (cf. Fig. 1). A detailed overview of the HIT facility is given in [1].

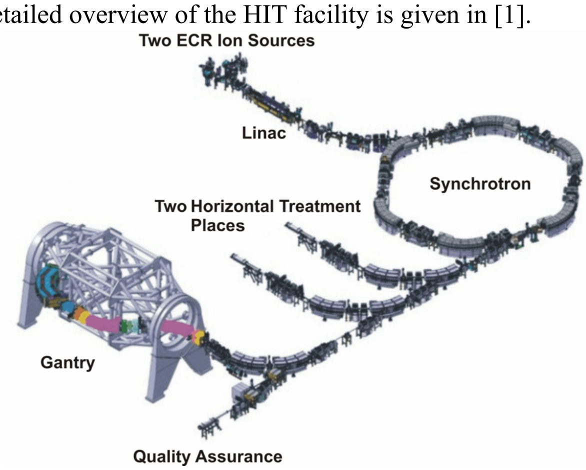

Figure 1: HIT accelerator facility.

Whereas all accelerator parts were produced by commercial partners, GSI Beam Diagnostic (BD) group acted as contractor for the delivery of the 92 different diagnostic devices of the HIT facility. This included the production of hardware (detectors, electronics etc.) as well as installation and commissioning of the devices and, finally, the integration of the data acquisition into the overall accelerator control system [2]. Nevertheless the software part of the beam diagnostic delivery was produced in close collaboration with an industrial partner (Eckelmann AG, [3]).

For the implementation of the HIT accelerator control system (ACS) a call for tenders was performed, covering the delivery of both, the complete set of hardware (PCs, timing system, device controllers etc.) and related control system software, including all necessary tools for machine operation, troubleshooting, safety, quality assurance etc. In a second step it was decided that the same commercial partner will also be contracted for the creation of the beam diagnostic data acquisition software in order to reduce interfaces and optimize synergy effects.

HIT BEAM DIAGNOSTICS

Requirements related to the routine operation of a medical facility are a) reliability of the devices, b) their maintainability and c) modularity and/or standardization of the equipment. The reliability of devices is related to their error tolerance, redundant layouts and intrinsically safe devices with interlock generation. To optimize the maintainability of BD devices, e.g. offline test functions are commonly used to allow fast troubleshooting in case of problems. Additionally the usage of commercially available parts allows for a fast replacement of erroneous modules without the need for an extensive stock of spare parts. Therefore a modular hardware structure with standardized components is an important prerequisite for a high operational availability of the medical accelerator facility. At HIT National Instruments PXI crates with embedded controllers [4] were chosen as a standard platform for the integration of the BD devices. In general NI8145 controllers with 266 MHz CPU and 256MB SDRAM are used except for cases demanding a higher performance, like e.g. the treatment of large data volumes for digital image processing. Here NI8176 controllers with 1.26 GHz CPU, 512MB SDRAM and an additional 15GB hard drive are installed. In order to standardize the requirements for the DAQ software the complete set of BD devices has been grouped to seven individual device classes with regard to the measured beam parameter:

- DC current measurement (Faraday-cups (dc-type), dc transformers)
- AC current measurement (Faraday-cups (ac-type), pulse current transformers)
- Profile measurement (SEM grids, multiwire proportional chambers)
- Phase probes (phase advance, time-of-flight)
- Beam position (beam position monitors)

- Event counting devices (Scintillators, ionization chambers, beam-loss monitors)
- Optical diagnostics (Scintillating Screens, isocenter diagnostics)

Each of these device classes is represented by one or more embedded PXI controllers.

DATA ACQUISITION LAYOUT

The data acquisition system for beam diagnostic devices at HIT generally consists of a hierarchy of three layers. The detector layer includes the sensor at the beam line, pre-amplifiers and in some cases also passive electronics for signal shaping or level adaptation. The range settings and test functions are also performed in this layer. PXI crates serve then as standard interfaces for signal digitization, I/O control and network communication towards the ACS. This digital I/O layer integrates different kinds of detectors that measure the same beam parameter. E.g. AC transformers and Faraday-cups are connected to the same PXI crate of the device class 'AC current measurement'. Thus the device classes embrace one or more PXI-crates, running identical LabViewRT software for data acquisition, status control and network communication. Fig. 2 schematically shows the layout of the DAQ system.

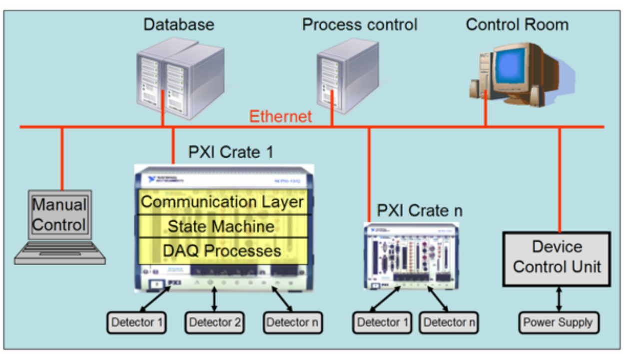

Figure 2: Schematic data acquisition layout.

The manual control software, used for troubleshooting and maintenance, operates directly on the digital I/O layer. The third layer is represented by the ACS that allows to control all device classes and is connected to the PXI crates via ethernet. The measurements are triggered either via user requests or, for automated data acquisition, via the process control of the ACS. The ACS process control is also the control instance for the state machines running on the PXI crates. For the ACS the PXI crates build up the same abstraction layer like the so-called 'device control units' (DCU), i.e. purpose-built interfaces for the control of e.g. power supplies and timing distribution, details are given in [5,6].

EXAMPLES

I) Manual Control Software

An important feature of the DAQ system is the low-level accessibility of all diagnostic devices via dedicated manual control software. The manual control software consists of a 'client', installed locally e.g. on a notebook used for maintenance purposes. The client allows the full control of the PXI crates without connection to the overall ACS. This is especially important during machine shutdowns, where the ACS is often inaccessible and maintenance of BD devices usually takes place. The access by manual control is restricted to adjustment modes of the facility, in all other operational modes the client is set to 'display-only' for online status control.

As an example Fig. 3 shows a screenshot of the GUI for manual control of profile grids (PG), offering the full functionality to control the status and read out the PGs. The lower insert shows the built-in data display. In this case the PG test function was activated that creates the comb-like structure by applying a current source to the wire grids.

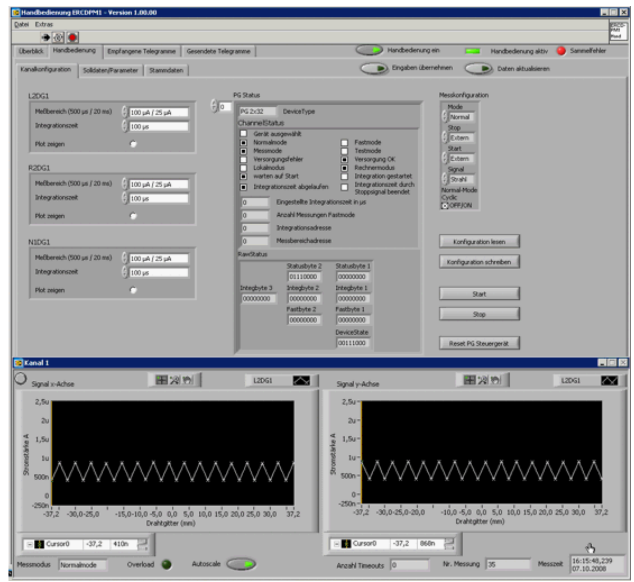

Figure 3: Manual control software for profile grids.

It has been a distinct design concept to strongly integrate the manual control software as part of the ACS from the very beginning. The intention was to keep the hierarchy of the system flat and to prevent 'branching' of control applications which often leads to data inconsistencies, undefined states or access conflicts. In the design presented here the DAQ system with its manual control is a monolithic building block of the ACS.

II) SD-Base

A screenshot of the basic control GUI for all beam diagnostic devices of HIT is depicted in Fig. 4. The background shows the main control GUI with a list of all devices in the various accelerator sections in the direction of the beam path, starting with the source branch 'QL' on the top and sorted by device classes from left to right.

All cells of the table have command button character. By clicking individual applications are started depending on the chosen diagnostic device. The foreground shows the GUI for slit control. The bottom part of this widget graphically displays the actual slit position and allows setting position values. The movement of the slits is of course restricted to several operational modes of the accelerator, e.g. the movement of intercepting diagnostic devices is prevented when the facility is operated in 'therapy mode', where intercepting devices would cause an unwanted and sometimes hazardous change in beam parameters. Therefore a row of square-shaped displays inform the user of the actual operational mode ('manual', 'exp', etc.).

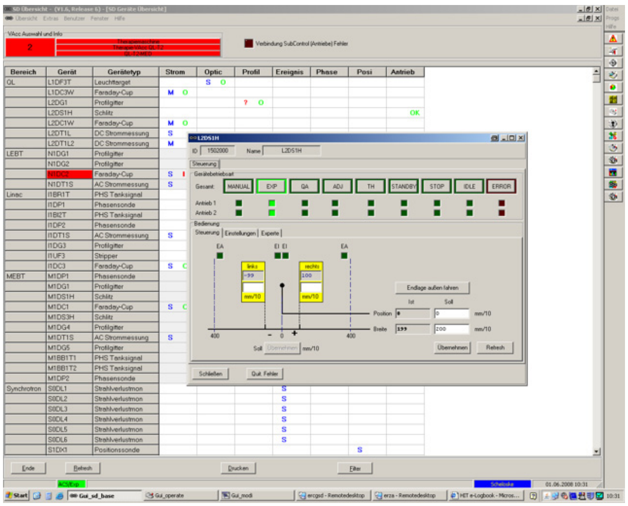

Figure 4: GUI 'SD-Base' for central control of all diagnostic devices, insert: widget for slit control.

III) Profile Measurement

The measurement software for profile grids is presented in Fig. 4. The upper two viewgraphs represent horizontal (left) and vertical (right) beam profiles measured with two successive profile grids in the medium energy beam transport section. In addition to the online display of the profiles, the beam position (SWPKT) as well as the beam width (FWHM) are calculated online.

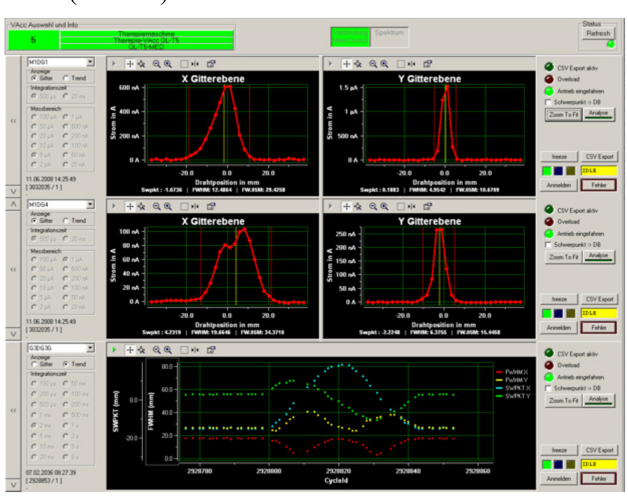

Figure 5: Online display of profile grids (top and middle) and trending of one MWPC for 80 synchrotron cycles.

The plot at the bottom of Fig. 5 depicts a profile measurement with a multi-wire proportional chamber (MWPC) in the high energy beam transport section. Here the display is set to 'trending mode', i.e. the evolution of beam position and width is plotted as a function of synchrotron cycles. This measurement mode is especially helpful for exact beam alignment and machine tuning. Also this GUI reflects the general strategy to integrate devices that measure identical beam parameters as close as possible. The GUI allows the direct comparison of the different detectors and, secondly, the concurrent display of online and trending data.

IV) Optical Diagnostics

As a second means for the detection of beam profiles, especially for very low beam intensities, scintillation screens are used in the HEBT section. The screenshot presented in Fig. 6 shows the read out and control of a so-called isocenter-diagnostic device. This is a special type of screen mounted outside the vacuum at the position where the ion beam hits the patient (the 'isocenter'). The two plots show the horizontal (top) and vertical (bottom) beam profile. The data of the scintillation screens and isocenter-diagnostics can be treated in exactly the same manner as the profile grid measurements.

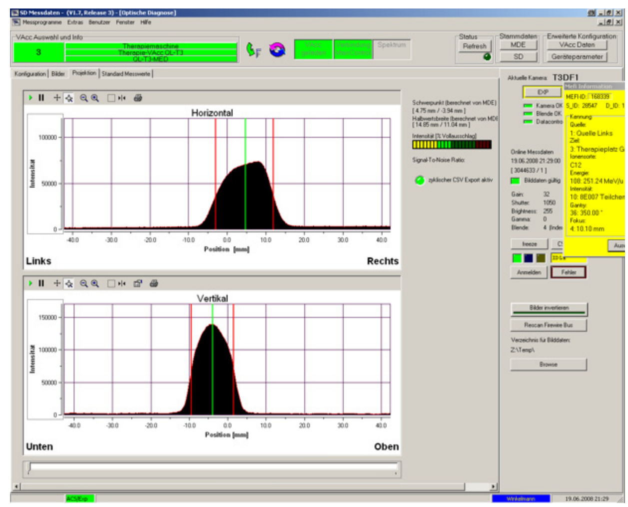

Figure 6: Profile measurement using isocenter diagnostics.

SUMMARY AND OUTLOOK

We have shown that by a flat three-layered structure all beam diagnostic devices of HIT have been seamlessly integrated in the accelerator control system, thus creating a monolithic DAQ system that has proven its operability already during the accelerator commissioning.

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REFERENCES

[1] D. Ondreka et al., Conf. Proc. EPAC2008, p. 979, Genoa, 2008.
[2] A. Reiter et al., Conf. Proc. EPAC2006, p. 1028, Edinburgh, 2006.
[3] www.eckelmann.de
[4] www.ni.com
[5] J. M. Mosthaf et al., WEP002, PCaPAC'08, 2008.
[6] T. Fleck et al., WEP021, PCaPAC'08, 2008.