Status of the Control System for the Therapy Facility HIT

T. Fleck, R. Bär, *GSI Darmstadt, Germany*

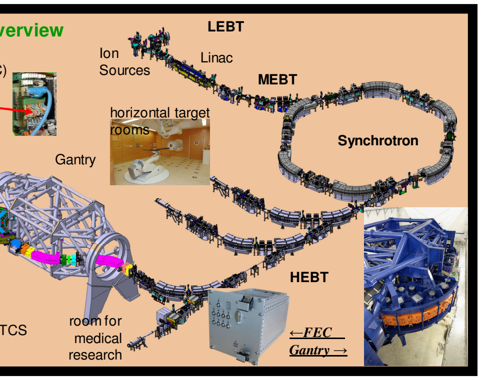
J. Mosthaf, *HIT Heidelberg, Germany*

Abstract

Shortly before first tumor patients will be treated with high-energy ions at the Heidelberg Ion Therapy Center (HIT) we give an overview of the accelerator control systems (ACS) special characteristics, present status and remaining functionality to completion. The ACS was designed and implemented by an all-industrial partner following functional specifications from GSI. At each of the three therapy rooms more than 20000 combinations of beam energy, intensity and focus can be requested by the therapy control system (TCS). The commissioning for carbon and proton ion beams has already been successfully conducted by GSI. We show how different operating conditions are implemented. Experimental research is possible while beam properties already verified within medical test procedures cannot be altered without following predefined work flows. All system and device parameters as well as all set values that possibly could change beam properties for patient treatment are securely locked or integrated into checksums. We also focus on functionality that had to be implemented to conform to the requirements that originated by the risk assessment of the ACS.

Facility, Control System Overview

- 1300 patients a year
- Different ions with up to 430MeV/u (C)
- 500 components, µs timing
- Real-time bus for accelerator events
- Special front-end controllers
  - flash memory for therapy settings
  - Motorola PowerPC processor
  - Altera Stratix FPGA
- Pulse-to-pulse variation
- Combinations of 250 energies, 6 foci, 15 intensities (EFI)
- Operation modes for therapy, QA, commissioning, experiments
- Use of standard industrial computers
- ORACLE database holds all CS data
- Interface to Therapy Control System TCS



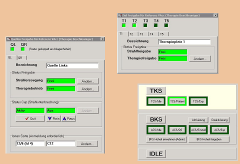
Interfaces to the Therapy Control System and Specifics of the ACS

Authorization, Beam Requests, Beam Paths

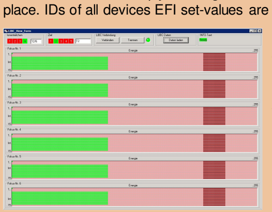
There exist three main system states ACS / TCS / IDLE and additional submodes for e.g. experimental usage or quality assurance. Beam paths have to be approved from the ACS for TCS usage. Any system state can only be activated if several global and device-specific checksums and status information in approved beam paths meet the specific requirements being highest for patient treatment mode.

Communication ACS↔TCS is established mainly with direct digital connection to the ACS timing master unit.

Upon each broadcasted ACS or TCS beam request additional verification based on reply messages and status information takes place. IDs of all devices EFI set-values are taken into account.



Beam Path clearance for patient treatment, assignment of operation mode / authorization



LIBC availability flags. In this example most EFI combinations are locked by the ACS

LIBC Interface, Reservation Queue

The TCS as a medical product uses its own interlock system since by no means the ACS is responsible for patients integrity. Entries in a reservation queue are necessary both from ACS or TCS to quit these TCS interlocks before beam can be delivered to a treatment room.

On the other hand the TCS can only execute accelerator cycles if the corresponding EFI combination was approved by the ACS.

In the TCS LIBC database[1] all ACS changes relevant to beam properties are logged and have to be accepted by the TCS – more often than not requiring additional quality assurance measurements.

In the LIBC all possible beam properties are defined in physical units.

[1](List of Ion Beam Characteristics)

top: measured synchrotron current from injection to extraction bottom: first online BAMS current (10/2008, not yet properly scaled) in an ACS GUI during patient treatment mode

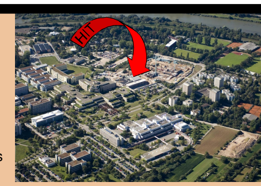
BAMS, Scanner Magnets, Spill Abort Devices

In patient treatment mode the TCS directly controls scanner magnets to deflect the beam across the tumor region.

The Beam Accelerator Monitoring System (BAMS), an important TCS interlock system (multiwire proportional and ionisation chambers), can be accessed from the ACS in experimental mode. Only since this month it provides an analog intensity signal to the ACS for monitoring during patient treatment or other modes of TCS operation.

Several power supplies have additional TCS interlocks for fast beam abort or interruption (spill pause); concurrent ACS events are triggered via the digital connection to the timing master.

Timeline



Aerial view of the facility in Heidelberg

2005 Developments Preceding Commissioning

- Prototypes of front end control units / intense tests
- Test facility at GSI (LINAC-RFQ). First CS versions

2006 First Commissioning Steps

- Set-up CS network, first power supplies, Ion source control
- LEBT section, current/profile measurements, viewing screens
- LINAC commissioning with different ion types
- CS timing important (rf units, chopper)

2007 Changeover to Operation Mode

- Commissioning of Synchrotron and beam lines to horizontal target rooms
- Calculation and interpolation of all device settings for whole set of beam parameters (E*F*I)
- Implementation of all beam diagnostic classes

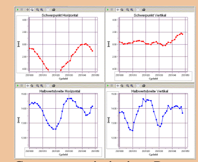
2008 ACS Finalization Phase, TCS Commissioning

- Beam requests by therapy control system
- Additional supervisions, IDs, checksums. All components integrated
- Gantry commissioning, beam optimization
- Risk assessment ACS
- Final revisions, ACS near completion

2009 Operation Phase

- Patient treatment
- Usage of medical research target room by medicine physicists

Console view



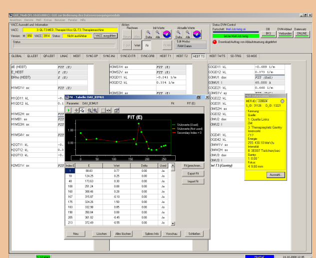
Gantry commissioning: Beam position and FWHM at tumor area as a function of Gantry angle

Calculation of Device Control Data

In experimental research ACS submode, all beam properties are adjusted using a sophisticated physical machine model with high level parameters.

Single EFI combinations can be calculated and executed. The whole EFI parameter space can be interpolated based on sampling points.

The calculation base can be switched from experimental to patient treatment settings to allow for fast realignment of therapy settings while different set-values may be optimized.

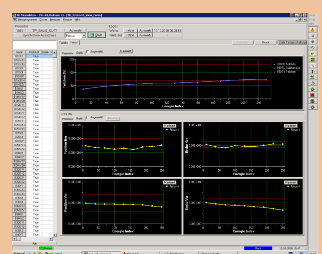


GUI for the physical machine model. Inset: energy fit for one parameter and commissioned sample values

Verification of Beam Properties

Prior to patient treatment beam properties have to be assured within the ACS on a daily base. Automated procedures (therapy protocols) have been set up and acceptable tolerances defined with an optimization between time expenditure and significance of the sample measurements.

Therapy protocols are run in ACS quality assurance mode using all devices therapy settings from flash memory while all supervisions for patient treatment are activated. If realignment is necessary, all changed data have to be transferred to devices flash memory following defined workflows.

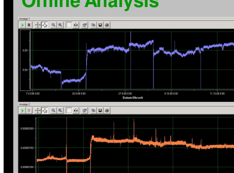


Example of therapy protocol showing measured particles and beam position behind the synchrotron

ACS Risk Assessment

All possible ACS problems that in TCS mode could lead to treatment with wrong beam properties had to be excluded. In the LIBC two IDs are assigned to each ion type. Devices and parameters are marked to be relevant to one of those IDs. Upon change the corresponding ID and a device checksum are incremented. Patient treatment mode only can be activated if this checksum has been written to the FEC flash memory and changes logged in the LIBC.

Offline Analysis



Tools for thorough offline analysis are implemented for error tracking and examination of historic or long-term behavior

History of extraction current (top) and extraction pressure (bottom) of one ion source

Current Status, Open Issues

By now most of the ACS functionality is implemented and has intensely been tested during machine commissioning and extensive test shifts.

From the technical point of view the ACS is ready to be used for patient treatment. About hundred minor open issues (missing functionality and bugs) are listed that have to be eliminated by the industrial manufacturer of the ACS. Final functional and safety compliance tests still have to be performed.

Patient treatment is expected to start early 2009 after certification of the TCS.

corresponding author:

Dr. Tibor Fleck
GSI Helmholtzzentrum für Schwerionenforschung GmbH

accelerator electronics and control systems / BEL

Planckstr. 1, 64291 Darmstadt
+49 (6159) 71-2075
t.fleck@gsi.de

Some of the GSI people involved in the project at a HIT ceremony :-)