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

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HIT - Heidelberg Ion Therapy Center

Accelerator Setup

Two parallel ECR-ion sources are used for production of protons and C-ions.

The injector linac consists of a combination of a RFQ and an IH-structure to accelerate the ions up to 7 MeV/u with a macropulse length of 300 µs.

The synchrotron has a circumference of about 64 m and a maximum magnetic rigidity of 6.6 Tm.

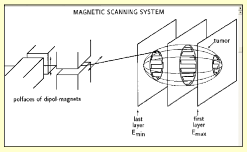
Beam Parameters

Carbon beam
Energy:
88 - 430 MeV/u
Intensitiy:
$2x10^6$ to $4×10^{10}$ ion/s
Spot size: 4 – 12 mm

Proton beam
Energy:
48 - 220 MeV/u
Intensitiy:
$8x10^7$ to $3×10^9$ ion/s
Spot size: 8 – 20 mm

Hadron Therapy

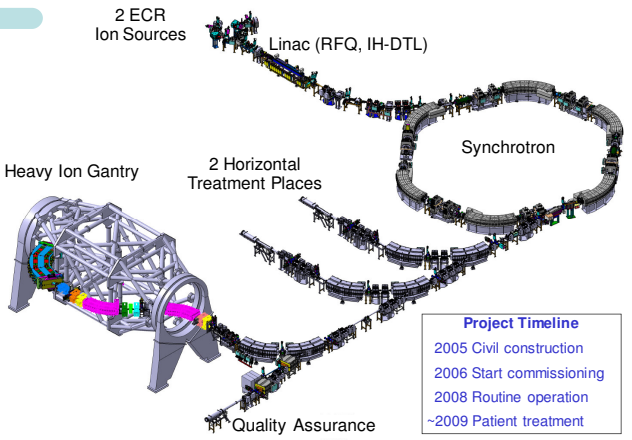
Intensity controlled raster-scan method



Treatment with low and high LET*-ions

Isocentric gantry for 360°-patient irradiations

LET*: Linear Energy Transfer



Project Timeline
2005 Civil construction
2006 Start commissioning
2008 Routine operation
~2009 Patient treatment

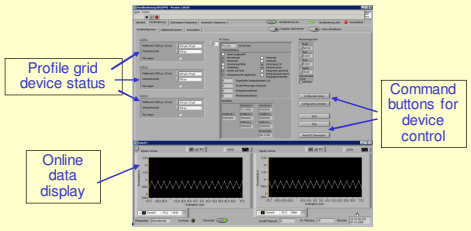
Diagnostic Devices

For standardization the complete set of BD devices is grouped to seven individual **device classes** with regard to the measured beam parameter:

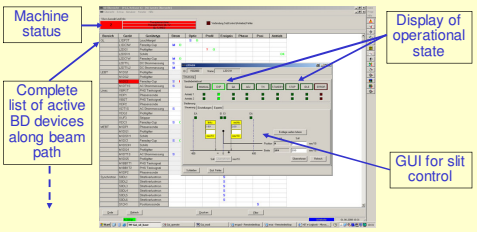
Device Class	BD Devices
DC current measurement	4 Faraday-cups (dc-type), 2 dc-transformers
AC current measurement	3 Faraday-cups (ac-type), 4 Pulse current transformers
Profile measurement	10 SEM grids, 13 Multi-wire prop. chambers
Phase probes	4 Phase probes, time-of-Flight
Beam position	6 Beam position monitors (shoe-box)
Event counting	13 Ionization chambers, 5 Scintillators, 6 Beam-loss monitors
Optical diagnostics	12 Scintillating screens, 3 Isocenter diagnostics

Manual Control Software

- Low-level accessibility of all beam diagnostic devices
- 'Client' installed on maintenance notebook
- Full control of PXI crates without connection to Accelerator Control System (ACS)
- Access restricted to adjustment mode of the accelerator
- 'Viewer mode' for display of device status during routine machine operation
- Example: **Manual control for profile measurement**



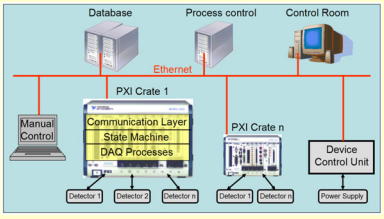
GUI 'SD-Base'



- Main control GUI for all beam diagnostic equipment
- BD devices are listed from top to bottom in direction of beam path (1 device per line, sorted by device class)
- Each cell displays status information of a) related data acquisition application, b) mechanic drive of intercepting devices (pneumatic / stepping motor)
- More specialized control features available by context menus and/or device class dependant user application

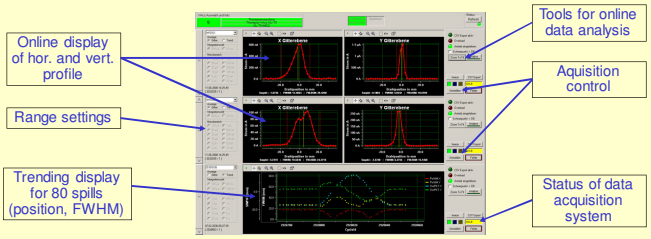
Data Acquisition Layout

- The DAQ system consists of a **hierarchy of three layers**
  - **Detector layer:** sensor at the beamline, pre-amplifiers, passive electronics for signal shaping, level adaptation
  - **Digital I/O layer:** PXI embedded controller, ADC, and I/O-board, for signal digitization, pre-processing, device control
  - **ACS layer:** distributed PCs and database for online data display, status and process control, data logging, offline analysis and automated measurements for quality assurance



- Each **device class** is represented by 1 or more PXI crates
- **PXI crates** serve as standardized platform for BD equipment
- ACS connection via GBit ethernet
- **State machines** on PXI crates are monitored by ACS process control
- PXI crates share abstraction layer with **device control units** (DCU)
- DCU: standard devices for active elements of beam transport system (power supplies, rf control, etc.) and timing

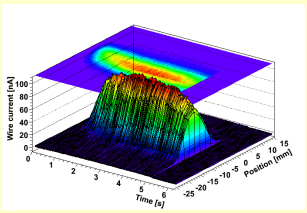
Beam Profile Measurement



Readout electronics

- Synchronous integration of all wire currents
- Multiplexed transmission of data to single differential ADC
- 16 integration times (100µs – 6 s)
- Remote controlled test function
- Single measurement (ext. trigger)
- Fast-mode: fast cyclic measurements of spill structure using one SEM grid (external start and stop signal)

Fast-mode measurements reveal fine details of the spill



Optical Diagnostics

Scintillating screens

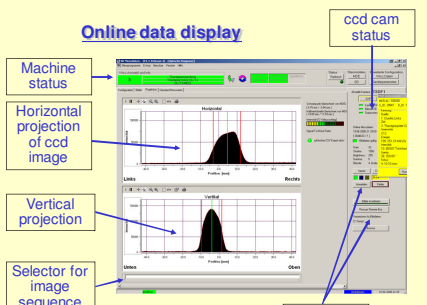
- 15 cameras linked via FireWire network
- 12 AVT Marlin for scintillating screens (8 bit)
- 3 low-noise Hamamatsu cameras for isocenter diagnosis (12 bit)

- Resolution: 0.3 mm / pixel

Isocenter-diagnostics mounted on patient robot:

- Matching of coordinate systems (machine / therapy)
- Machine adjustment
- Quality assurance

Online data display



3d-offline analysis of isocenter-diagnostics

- Beam width
- Beam profile
- Spot homogeneity