Next-generation dose delivery system for Particle Therapy

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Background

Cosylab and MedAustron have been involved in the co-development of a novel dose delivery system, the C-DDS. At the MedAustron ion beam therapy synchrotron, this system is responsible to accurately and safely deliver the prescribed dose by controlling and monitoring, in real-time, all clinically relevant parameters of the scanned particle beam.

Outlined are the goals of the development program:

- Allow MedAustron to safely treat patients at higher beam intensities (up to nominal/peak particle rate of $2x10^{10}/2,5x10^{11}$ protons per second and $1x10^{9}/7,5x10^{9}$ carbon ions per second), increasing the number of patients and indications (e.g. large volume tumours) that can be treated at the facility.
- Design the dose delivery system in a way to be able to support future machine upgrades, such as: advanced beam monitors, commissioning and QA automation, advanced dose delivery methods and real-time anatomy/beam monitoring.
- Design the dose delivery system design in a way to be able to integrate it into different proton and ion beam therapy centers, to be able to adapt to different: accelerator types, particle species, room configurations (single/multiple fixed or gantry nozzles) and geometries, existing interfaces of the PT centers.
- Provide well-designed user-, software- and hardware interfaces to allow for implementation of efficient user workflows during clinical operation, commissioning, QA and research.
- Be integrated out of the box with the existing MedAustron system interfaces and Cosylab software for particle therapy – C-TCS (Treatment Control System) and C-ACS (Accelerator Control System).

System Requirements and Design Principles

During the system design stage, the following functionality, performance and design contraints were identified as crucial in order to satisfy the goals as outlined above:

- **Fast speed of reaction:** To satisfy the requirements of IEC 60601-2-64, the design goal for C-DDS for MedAustron to react to a beam parameter out of bounds is 50 µs (particle rate) / 120 µs (beam position). This represents challenging design requirements for ionization chambers and data processing logic for beam monitoring.
- **Quasi-discrete scanning:** The algorithms of the C-DDS are designed in a way that the beam does not need to be turned off between spots. The delivered dose is accurately monitored and assigned to the correct spot.
- **Dynamic particle rate control:** The C-DDS automatically controls the beam intensity based on the weight of previous, current and next spots.
- **Beam position correction:** The position drift during extraction of the beam is compensated using scanning magnet corrections, based on real-time measurement of the beam.
- **Multiple modes of operation and configuration control:** The C-DDS supports different modes of operation – Clinical, Service, QA, Manual. Based on the mode, the C-DDS allows usage of different system configurations and functionalities.
- **Extensive software interface:** The software interface allows control and insight into the status and detailed logs of the C-DDS to authorized clients (e.g. clinical software, service tools).
- **Customizable interfaces:** The external software and hardware interfaces of the C-DDS are designed in a way to be customizable for integration with different existing interfaces of the PT facility and to allow future upgrades.
- **Modular architecture:** The functionality of the system is split into modules, allowing fast replacement in case of hardware failures and easier upgrades with future functionality.
- **Hardware platform:** A high performance Commercial-Off-The-Shelf hardware platform is used, based on an open standard (MTCA.4). This allows mature and tested hardware to be used and prevents hardware vendor lock-in.
- **Simulated test environment:** For testing, commissioning and service procedures, a validated simulator of external interfaces is developed.

Conclusions

The main performance requirements, design principles and architecture of a novel dose delivery system, used in the MedAustron facility were presented. The system is currently in development and will be integrated into MedAustron and extensively tested in 2021.

As part of the development, functional prototypes were developed and tested in the MedAustron research room. Figure 4 presents a scan acquired during one of the prototype tests with the MedAustron proton beam.

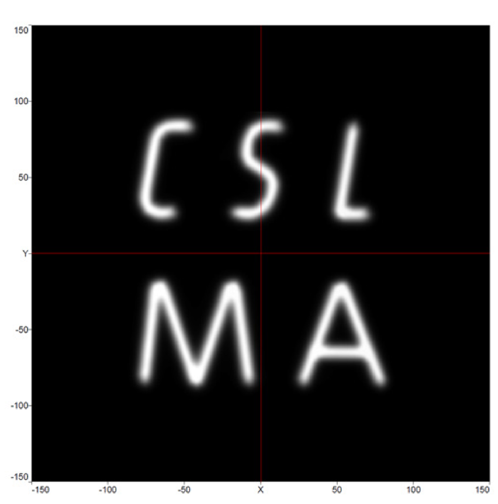


Fig. 4: Beam scan, delivered with a C-DDS prototype at MedAustron

System Architecture

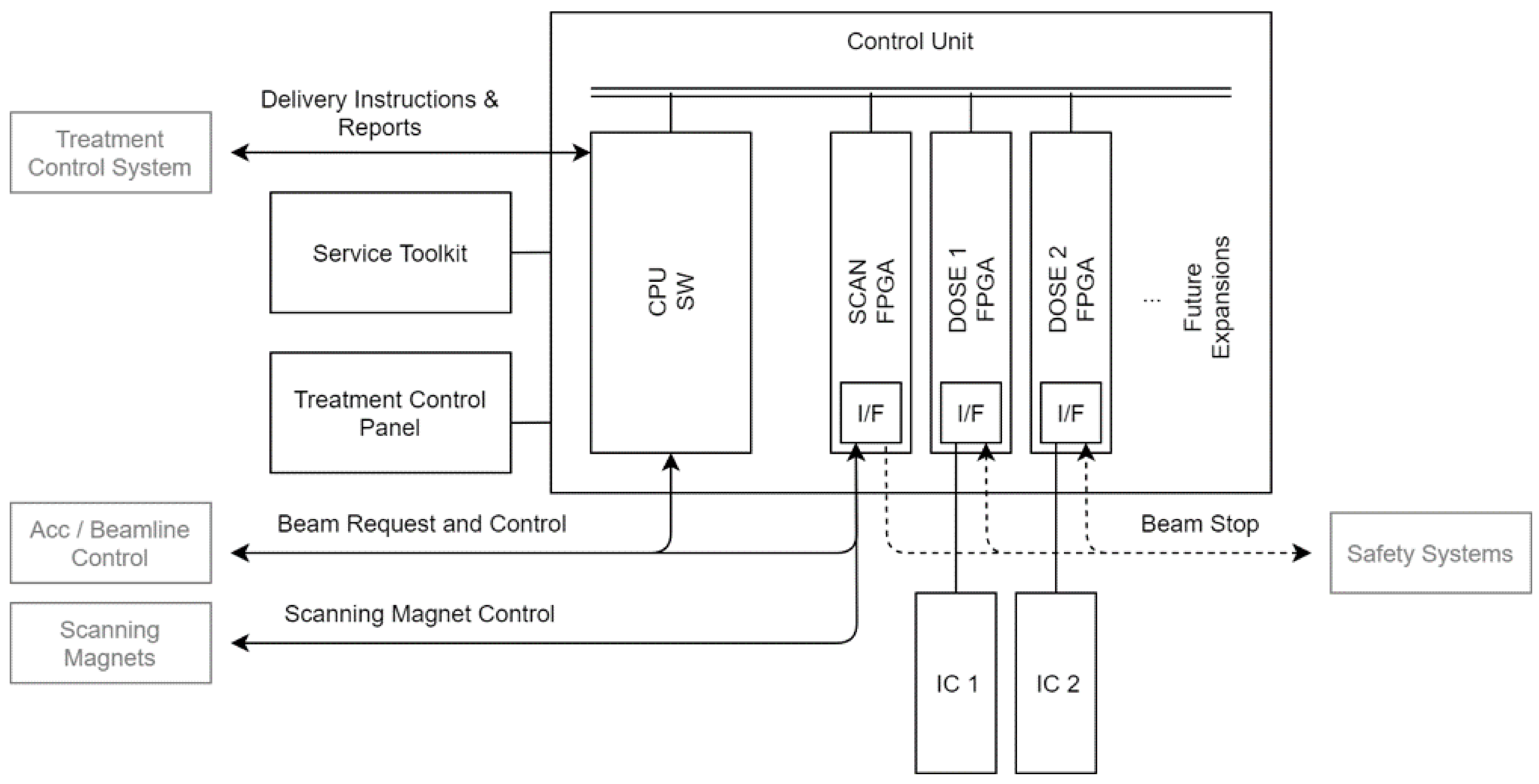


Fig. 1: C-DDS System Architecture

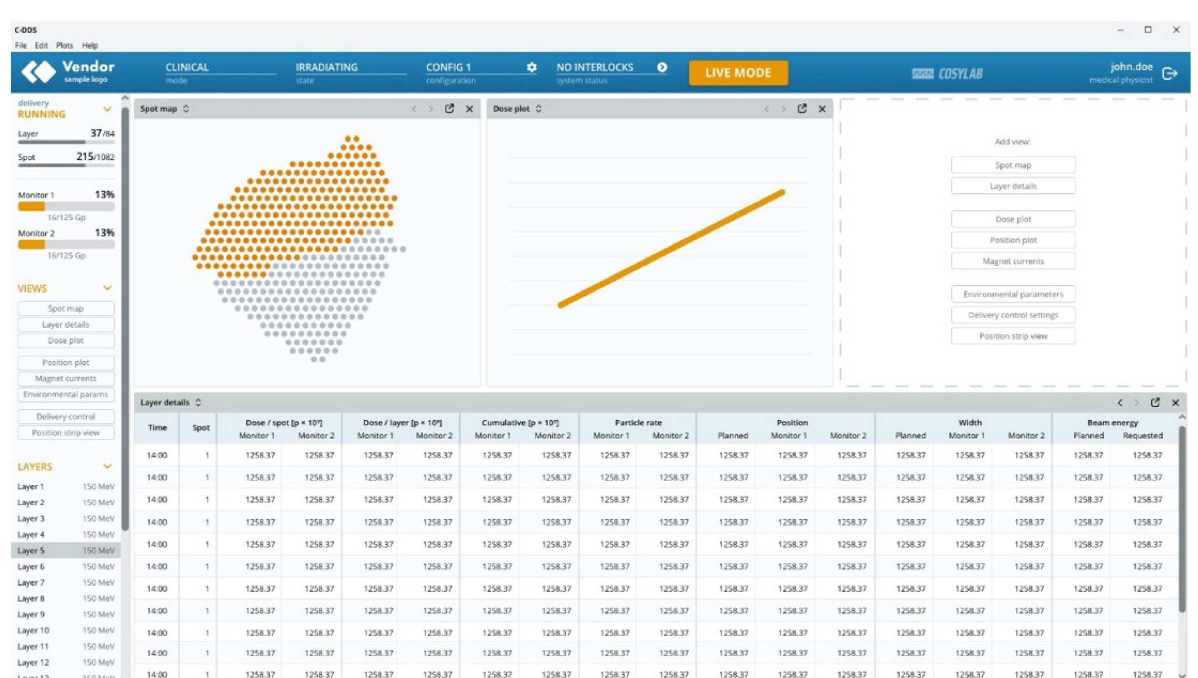
Figure 1 represents the main components and external interfaces of the C-DDS. The individual components are:

- The **Control Unit**, based on COTS MTCA.4 hardware platform, containing the software (non-real time interfaces and functionality – spot map processing, logging, TCS interface etc.) and FPGA firmware (scan magnet control, beam parameter calculation, interlocking).
- Redundant **Ionization Chambers** for measurement of beam parameters.
- A hardware **Treatment Control Panel** (Figure 2) to display information and allow basic control of the beam to the user, developed to satisfy the requirements of IEC 60601-2-64, is integrated into the system. The design is done in a way to support different room configurations (gantry, single/multiple fixed nozzles).

Fig. 2: C-DDS Treatment Control Panel

- **Service Toolkit** (Figure 3) software, allowing the users access to configurations, low-level data (status, logs, interlocks) and service functionality through a GUI.

Fig. 3: C-DDS Service Toolkit



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