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DELIVERY OF SPECIAL MAGNETS FOR THE MEDAUSTRON PROJECT

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Abstract

Ten different types of kickers, bumpers, and electrostatic and magnetic septa, along with certain power supplies and associated control system components, have been designed in a collaboration between CERN and MedAustron for an ion therapy centre in Wr. Neustadt (Austria). This paper focuses on the status of the special magnets work package and the improvements applied during the production. The design parameters are compared with data from measurements, hardware test and initial commissioning. The major factors contributing to the successful completion of the work package are highlighted.

INTRODUCTION

In 2009 the work package "Beam Transfer Systems" was established at CERN by MedAustron, in close collaboration with the Accelerator Beam Transfer group of the CERN Technology Department, based on a partnership agreement between CERN and EBG MedAustron GmbH [1]. The aim of the work package was to ensure the design and production of the special magnets for the MedAustron accelerators. The design of the accelerator was initially based on CERN's PIMMS study [2] which was realized for the first time at CNAO (Pavia, Italy).

The scope of the work package covered in total 19 beam line elements of 10 different and unique types as well as 7 different types of associated power converters and pulse generators [3, 4]. Despite the availability of a similar design for most of the elements [2, 5], in the end all had to be re-designed to adapt to the latest technology and new requirements for the MedAustron facility.

FAST DEFLECTOR

In the Low Energy Beam Transfer (LEBT) line a fast (300 ns rise and fall times) electric field device called a "Fast Deflector" (EFE) is used to chop the beam. Design and production of a two electrode beam line device [6] as well as the associated fast pulse generator [7] and low level controls [8] was entirely carried out by CERN and MedAustron. A prototype was successfully tested in the LEBT, deployed for test purposes at CERN, and only minor modifications to the delivered system were necessary. The measured rise time was 230 ns. The device has now been operating for one year, without any failure.

SEPTA

For beam injection and extraction purposes two electrostatic septa (ESI, ESE) were newly developed and built at CERN. Six magnetic septa (MST, MSE) were designed by MedAustron, manufactured in industry and measured at CERN. The design of the electrostatic septa is outlined in detail in [6], construction and initial testing is reported in [9]. Installation, conditioning, and commissioning at MedAustron were carried out in collaboration with CERN experts and were successfully concluded in time.

The injection and extraction lines (Fig. 2) were completely redesigned, w.r.t. PIMMS; this resulted in a reduction to only two different types of magnetic septa [10]. The magnets were produced in industry: MedAustron provided a common batch of steel for all its magnets to ensure best fitting parameters. The laminated yokes were glued together and passed all mechanical tests: however it turned out that a careful inspection of the lamination coating was necessary, before stacking and curing, to ensure a solid yoke construction.

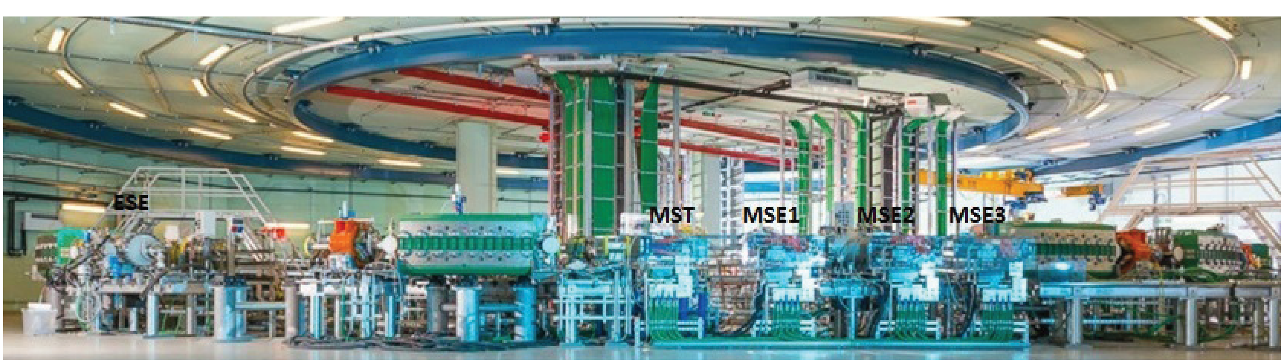

Figure 1: The MedAustron Synchrotron during installation (ESE (below gangway), blue: MST, MSE (High Energy Beam Transfer (HEBT)) from the centre to the right; green: main magnets, orange: quadrupoles).

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In order to increase the long-term reliability of the extraction septa, a radiation hard cyanate ester resin from CTD was used for coil moulding: this was the first ever application of this resin in an industrial series production of accelerator magnets.

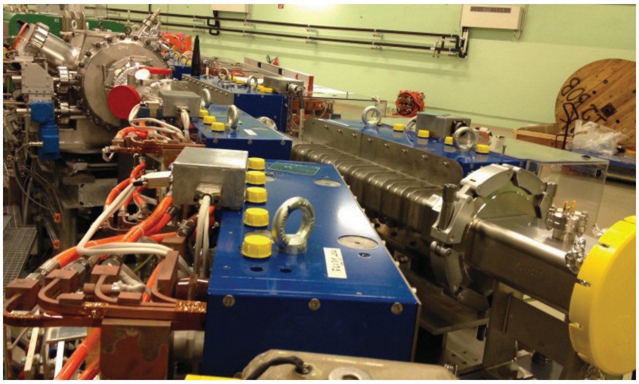

Figure 2: Injection/extraction region: 2 MST Septa (blue) in the front, 1 ESI tank at the back and 4 extraction septa (blue) at the right (only 2 visible).

Final testing at CERN showed that all magnet design parameters [11] were met, as judged from temperatures (Fig. 3) and also measurement of the magnetic fields. Hence there will be no need for additional trimming power supplies. A novel layout will also help MedAustron to significantly save on maintenance and operating costs [10]. The injection line was successfully commissioned with beam in early 2014.

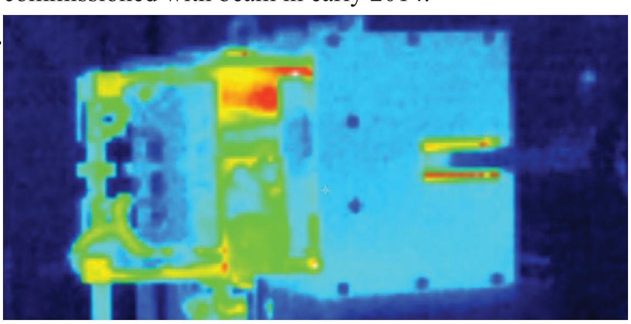

Figure 3: Magnetic septa during full power test at CERN. Thermal image showing coil and water cooling circuit functionality (red: 50°C, green: 37°C, dark blue: 25°C).

FAST PULSED SYSTEMS

The fast pulsed systems work unit comprised two injection bumpers (MKI), two dump bumpers (MKS), one tune kicker for each plane (MTH/MTV) and four chopper dipoles (MKC) as well as the associated power converters (PKI, PKS, PKT, PKC) [4]. All systems, except the tune kicker pulse generator, were significantly redesigned by MedAustron. All systems were manufactured in industry.

Injection and Dump Bumper Systems

The MKI and MKS bumper magnets (Fig. 4) were manufactured without any major modification w.r.t. the design. Only a number of dedicated holes had to be applied to the internal insulation layers to enable the moulding agent to properly enter all corners and voids. Some optimisation of the PKI and PKS was necessary to pass EMC tests successfully.

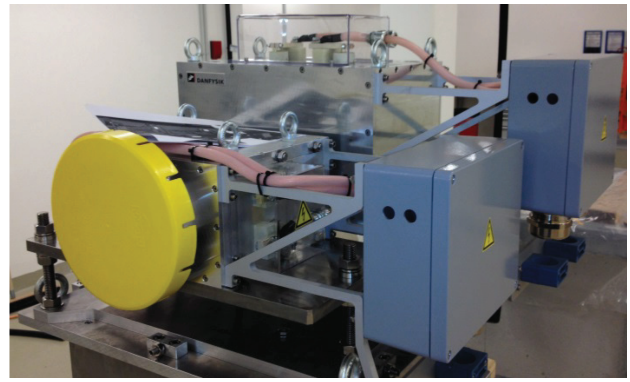

Figure 4: One MKI and one MKS magnet ready for installation (already pre-aligned on the support table and equipped with one continuous ceramic vacuum chamber).

Both magnets and their associated power converters were installed and commissioned successfully at MedAustron. Figure 5 shows charging current and the linear ramp-down during beam injection for different peak currents (corresponding to different beam energies).

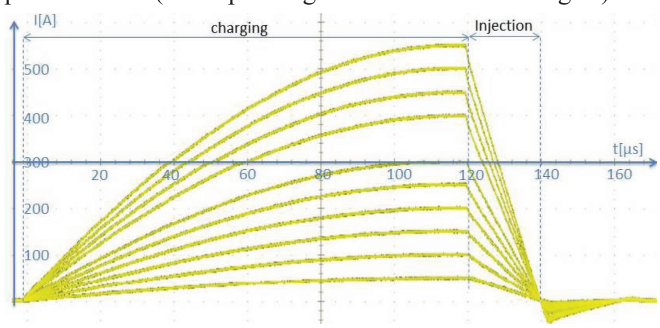

Figure 5: Injection bumper current during test operation.

Tune Kicker System

The tune kicker magnets (MTH, MTV) were lengthened w.r.t. the original design to increase the kick strength. The pulse generator design was copied from CNAO without changes. Detailed studies of the resistivity and thickness of the inner coating of the ceramic vacuum chamber were carried out to determine the effect on the fast field rise time (100 ns) of the tune kickers [12, 13].

During production minor changes were applied to the magnets concerning HV safety of cable connections, but major effort had to be allocated to the HV coils (Fig. 6). The HV feedthrough design was improved to hold off the 20 kV AC test voltage. The coil painting procedure needed to be redeveloped due to changes in the chemical composition of agents used.

Some changes needed to be deployed during the production of the pulse generator (up to 35 kV, 2100 A) to comply with EMC requirements and to avoid corona effect on the striplines. Final system delivery is expected for Q2/2014.

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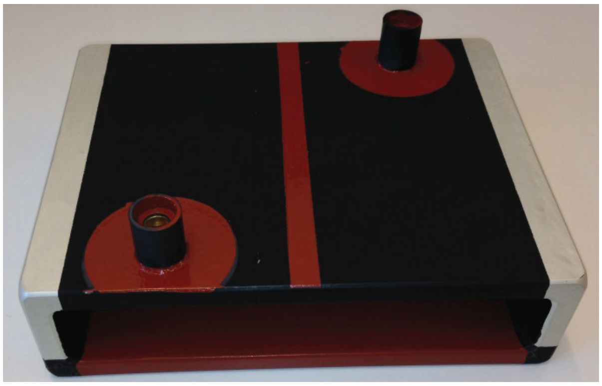

Figure 6: “Painted” MTV coil. Silver: silver paint; red: insulation varnish; black: semiconducting layers.

Chopper Dipole System

The four 640 A chopper dipoles (MKC) were redesigned (length, aperture and coils). Special care was taken during the manufacturing process, as well as during additional testing, to comply with the stringent requirements for the operation in the HEBT [14].

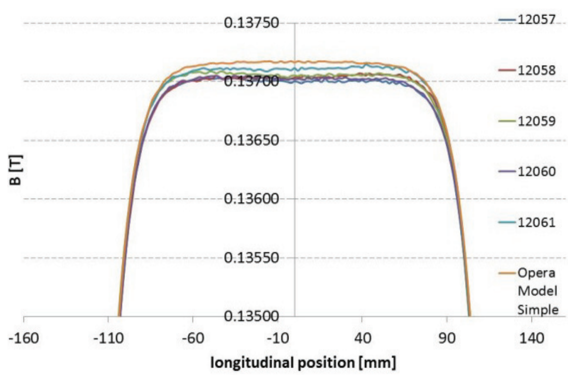

Figure 7: MKC magnetic measurements.

Figure 7 shows the results of the magnetic measurements: they are in very good agreement with predictions; the spread between magnets is within the specified ±0.2%. The PKC was tendered separately, in 2013, as it had to be compliant with and integrated into the beam delivery system beforehand. Production is still ongoing in 2014.

PROJECT MANAGEMENT

The partnership agreement between CERN and MedAustron was vital for the setting up of the work package and its success in delivering the systems, with the required quality, in time with the project schedule. The MedAustron management decided to outsource most production activities. Whilst work units placed directly at CERN were relatively easy to steer and follow up, those outsourced to industry needed considerably more resources for contract follow-up than initially foreseen. The close collaboration with CERN was essential in the technical follow-up of production items to ensure timely delivery.

CONCLUSION

The fast deflector, electrostatic septa and their power supplies have been designed and produced at CERN. The magnetic septa, fast bumper and kicker systems were redesigned by MedAustron and subcontracted to industry for manufacture. For the “in house” developments no significant issues were observed, however the outsourced parts took more resources for follow up than initially foreseen. The majority of the items were delivered, installed and commissioned successfully without major surprises. At present the tune kicker system and the chopper dipole power supply remain to be delivered.

REFERENCES

[1] M. Benedikt et al., “MedAustron-Project overview and status”, Eur. Phys. J. Plus (2011) 126: 69.
[2] P. Bryant et al., "Proton-Ion Medical Machine Study (PIMMS)", CERN-PS-2000-007-DR, Aug. 2000.
[3] J. Borburgh et al., “Special magnets for medical accelerators”, PHE 2010, Geneva, February 2010.
[4] J. Borburgh et al., “Design and Development of Kickers and Septa for MedAustron”, Proc. IPAC10, Kyoto, May 2010.
[5] L. Sermeus et al., “The Design of the Special Magnets for PIMMS/TERA”, Proc. EPAC04, Lucerne, July 2004.
[6] J. Borburgh et al., “Design of Electrostatic Septa and Fast Deflector for MedAustron”, Proc. IPAC11, San Sebastian, Sept. 2011.
[7] T. Fowler et al., “Design and Measurements of a Fast High-Voltage Pulse Generator for the MedAustron Low Energy Transfer Line Fast Deflector”, Proc. IPAC12, New Orleans, May 2012.
[8] P. Hübner, “A Digital Hardware Design to Control and Monitor a High Voltage Pulsed Power Supply for the Electrostatic Fast Deflector”, PPPS-2013, San Francisco, June 2013.
[9] J. Borburgh et al., “Construction and Initial Tests of the Electrostatic Septa for MedAustron”, Proc. IPAC13, Shanghai, May 2013.
[10] T. Kramer et al., “Proposal for a novel extraction layout”, EN100315-a-TKR-V0.5, Geneva, 2010.
[11] T. Stadlbauer, “Optimization of Special Magnets”, Diploma Thesis, UAS Kaiserslautern, 2010.
[12] M.J. Barnes et al., “Calculation of Metallization Resistivity and Thickness for MedAustron Kickers”, Proc. IPAC11, San Sebastian, Sept. 2011.
[13] M.J. Barnes et al., “Effect of a Metallized Chamber upon the Field Response of a Kicker Magnet: Simulation Results and Analytical Calculations”, Proc. IPAC12, New Orleans, May 2012.
[14] T. Kramer et al., “Risk Assessment of the Chopper Dipole Kicker Magnets for the MedAustron Facility”, Proc. IPAC11, San Sebastian, Sept. 2011.