DESIGN OF ELECTROSTATIC SEPTA AND FAST DEFLECTOR FOR MEDAUSTRON

J. Borburgh, T. Fowler, A. Prost, CERN, Geneva, Switzerland;
T. Kramer, T. Stadlbauer, MedAustron, Wr. Neustadt, Austria

Abstract

For the MedAustron facility under construction in Wiener Neustadt, three electric field deflectors are developed in collaboration with CERN. A fast deflector is used in the Low Energy Beam Transfer line to chop the beam. The chopped beam is swept onto a Faraday cup for measurement purposes and to stop beam being sent towards the synchrotron. For the multi-turn injection of protons and ions, as well as for the slow extraction from the synchrotron, electrostatic septa are used. A novel design for MedAustron includes an inversed cathode/anode support and high voltage feedthroughs rated for 150 kV. The possibility for a higher voltage will significantly improve the conditioning process of the septa surfaces. This paper describes the requirements of these devices as well as the mechanical design and strategies adopted for their power supplies.

INTRODUCTION

For the MedAustron medical accelerator [1], three electric field deflectors are being developed. A fast deflector [2] is employed to sweep the beam onto a Faraday cup [3], allowing beam measurements but also to stop the beam being sent to the synchrotron.

To allow multi-turn injection into, and resonant extraction from the synchrotron [4], electrostatic septa are used. This paper describes the requirements and design of these devices and their associated power supplies.

FAST DEFELECTOR

Mechanical Design

In the Low Energy Beam Transfer line a fast deflector (EFE) is used to chop the beam (Fig. 1). The EFE works for a fixed beam energy of 8 keV/u (for protons and ions with equivalent charge/mass ratio). The maximum deflection is 245 mrad. The baseline design foresees the beam to be swept in the horizontal plane onto a Faraday cup (FCC) for measurement purposes but also to stop the beam being sent towards the synchrotron. However, if the need arises, the deflector/Faraday cup assembly can be installed rotated by 90° to allow the beam to be swept in the vertical plane onto the Faraday cup. The beam acceptance in the plane of the deflection is 70 mm. To minimise the required voltage the electrodes are installed under a 9.8 mrad angle w.r.t. the central beam axis (Fig. 2). This permits the use of compact High Voltage (HV) feedhroughs and reduces the parasitic capacitance of the electrodes.

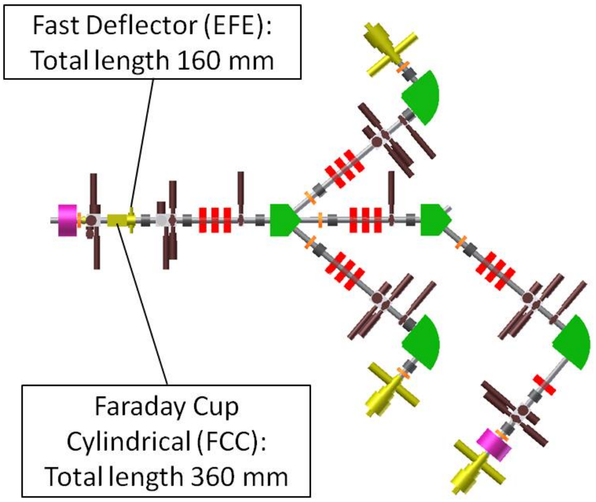

Figure 1: LEBT with source stations (yellow) and the fast deflector as well as the Faraday cup.

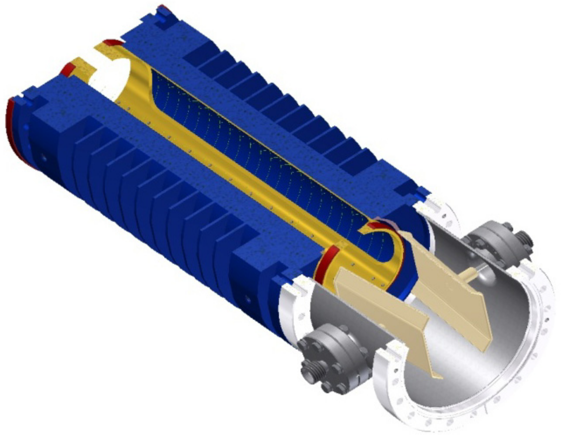

Figure 2: The EFE (grey) installed upstream of the FCC (blue), tapered EFE electrodes shown in beige.

The EFE as well as the FCC were modelled [5] to compute the field using Opera finite element software from Cobham. The cross sectional shape of the electrodes was optimised to achieve integrated field homogeneity of ±5%. Although the field strength on the electrodes would allow the use of stainless steel, these will be made of titanium instead to reduce weight, and allow them to be installed directly onto the feedthroughs, avoiding additional electrode supports. The principal device parameters are shown in Table 1.

Table 1: Principal EFE Parameters

Overall Length	160	mm
Electrode Length	120	mm
Electrode Gap Upstream	70	mm
Electrode Gap Downstream	90	mm
Integrated Field Homogeneity	±5	%
Good Field Region (h×w)	60×60	mm
Max. Electrode Voltage	± 6	kV

Power Supply Design

The EFE electrodes will be connected in a differential manner to a bipolar power supply providing ±2.5 kV. With a total differential potential of 5 kV across the electrode gap, the beam will be normally deflected onto the Faraday cup.

Transfer of the beam into the LEBT and MEBT, and ultimately into the synchrotron, will be achieved by pulsing the electrode voltages. Using a push-pull switch configuration as shown in Fig. 3, the electrode voltages will be taken to zero for the required injection period of around 100 µs. To optimize injection into the synchrotron, the beam must be switched from its position on the Faraday cup to the transfer trajectory in less than 300 ns. To keep the beam divergence at the RFQ inlet below 255 µrad and the beam displacement below 82 µm at the solenoid, the residual field must be below 22.2 V/m in the EFE when the beam is being sent to the synchrotron [6]. This implies that the residual voltage between the plates should be below 1.8 V. To meet these stringent requirements it will be necessary to locate the switch elements of the power supply as close as possible to the EFE; a maximum transmission cable length of 2 m is envisaged. Slow control of the power supply will be via a PCO FED [7] card connected to the MedAustron Accelerator Control System, whilst pulse control will be fed by timing signals supplied from the Main Timing System (MTS). The MTS will also ensure synchronisation of the EFE pulse with that of the synchrotron multi-turn injection bumper system.

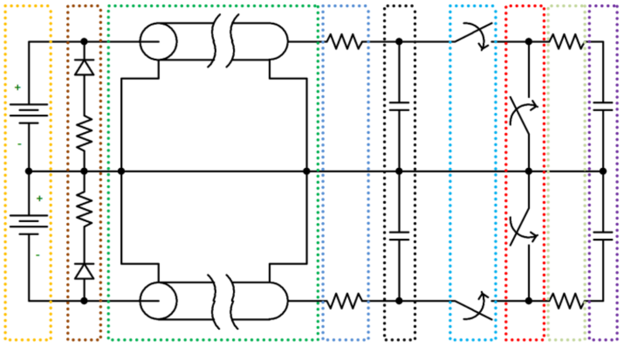

Figure 3: Simplified EFE power supply design, with (from left to right) off-the-shelf bipolar power supply; over voltage suppressor; ~10m transmission line; charging resistor; buffer capacitors; turn-on switches; turn-off switches; matching resistor; EFE electrodes.

ELECTROSTATIC INJECTION SEPTUM

Mechanical Design

The electrostatic septa (see Fig. 4) are located under vacuum, and use titanium cathodes and molybdenum septum foils. The hollow anode supports preserve the beam impedance as much as possible (Fig. 5).

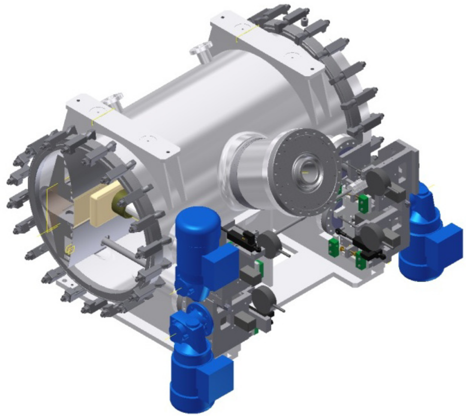

Figure 4: 3D model of an electrostatic septum tank with anode/cathode positioning system.

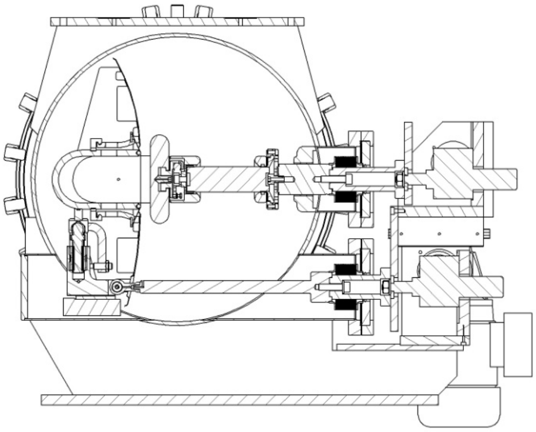

Figure 5: Cross section of electrostatic extraction septum.

The cathode and anode shape are chosen such as to minimise the electric field amplification on the HV components and to obtain the required field homogeneity in the gap. The principal septum parameters are indicated in Table 2. The injection septum (ESI) provides a relatively large deflection angle, and therefore the septum and cathode are bent at 60 mrad to minimise the required gap width whilst maintaining the required beam acceptance. The extraction septum (ESE) provides a moderate deflection of 2.5 mrad, hence the septum and cathode are straight.

The High Voltage (HV) feedthroughs of the septa are located on the same side of the vacuum vessel as the remote displacement system for the cathode and anode to gain space for the extraction channel on the other side. The nominal voltage required is less than 70 kV; however the feedthroughs and cathode supports are designed for up to 150 kV to allow sufficient margin for HV conditioning. To validate the HV feedthrough design, tests were carried out on the HV feedthrough prototype and its HV deflector, using a PS septum and a small dummy cathode attached to the prototype feedthrough. This assembly was conditioned up to 250 kV, with less than 5 μA of DC current, while up to 210 kV the remaining DC current was $< 1\mu$A (the measurement threshold).

Table 2: Principal Parameters for the Injection and Extraction Septa

	Injection	**Extraction**
Particle Energy [MeV/u]	7	400
Equivalent magnetic length [mm]	600	800
Physical length flange to flange [mm]	855	1055
Deflection angle [mrad]	60	2.5
Septum thickness + screen [mm]	0.1	0.1
Gap width [mm] (min., max.)	25 (15,35)	15 (10,25)
Septum angle [mrad] (min., max.)	0 (- 5,5)	0 (- 5,5)
Septum position w.r.t. orbiting beam centre [mm] (min., max.)	41 (31,51)	35 (25,40)
Cathode position w.r.t. orbiting beam centre [mm] (min., max.)	66 (46,86)	50 (35,65)
Cathode length [mm]	555	770
Septum length [mm]	660	860
Septum height [mm]	74	74
I_{nom} [A]	$< 10^{-4}$	$< 10^{-4}$
V_{nom} [kV]	69.7	63.7
$E_{nom} = E_{max}$ [MV/m]	2.79	4.26
Required Good Field Region w × h [mm^2]	25 × 33	15 × 28.8
Calculated Good Field Region w × h [mm^2]	25 × 55	15 × 55
Field quality [%]	± 1	± 0.5

Power Supply

Criteria for the power supply of the electrostatic septa have been evaluated and two functions have been identified:

- Primary: Precise and stable DC HV supply up to the maximum operating voltage of 70 kV.
- Secondary: Availability of a maximum voltage of 150 kV for HV conditioning.

In order to guarantee the accuracy, reproducibility and stability it is deemed useful to limit the main power converter (PCO) maximum voltage to levels not far above the maximum required voltage for operations. Thus the decision was made to use two set-point driven DC high voltage PCO with a maximum voltage around 80 kV. Another 150 kV PCO will be used for conditioning, but could also serve as a spare if required. All PCO will be situated in the special equipment room on the first floor and thus will have quite long cables of up to 80 m. First investigations and long term experience with CERN equipment showed that for such distances the "PCO-built-in" spark detection systems might not be sufficiently sensitive. Despite the fact that the improved septa design is optimized for low spark rates it is mandatory to have a reliable spark detection system for the extraction septum in place. Therefore space is provided for a pick up in the HV connector on the HV feedthrough.

The electric circuit will also comprise HV protection resistors close to the feedthrough to decouple as much as possible the energy stored in the transmission cable from the septum, in case of a spark. This is to avoid that too much energy will be deposited during a flash, which otherwise would damage the anode/cathode surfaces.

CONCLUSION

The mechanical design of the EFE is completed following in-depth field studies of the EFE and the associated Faraday cup. It is expected that the device is ready for installation by early next year. A basic circuit design for its power supply is completed, which will allow the EFE to achieve the very challenging dynamic field requirements.

The field studies for the electrostatic septa are completed, manufacture is launched and they are expected to be completed in 2012. The septa will each be powered with high precision and high stability DC power supplies of 80 kV, while the conditioning will be done with a separate 150 kV power supply.

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