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MASSLESS BEAM SEPARATION SYSTEM FOR INTENSE ION BEAMS

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Abstract

The ExB chopper [1] in the Low Energy Beam Transport (LEBT) section of the accelerator-driven neutron source FRANZ [2] will form the required pulses with a repetition rate of 257 kHz out of the primary 120 keV, 50 mA DC proton beam. A following beam separation system will extract the deflected beam out of the beamline and minimize the thermal load by beam losses in the vacuum chamber. To further avoid an uncontrolled production of secondary particles, a novel massless septum system is designed for the beam separation.

The septum system consists of a static C-magnet with optimized pole shapes, which will extract the beam with minimal losses, and a magnetic shielding tube, which will shield the transmitted pulsed beam from the fringing field of the dipole. The magnetic field and the beam transport properties of the system were numerically investigated. A main deflection field of about 250 mT was achieved, whereas the fringing field was reduced to below 0.3 mT on the beam axis at 60 mm distance from the dipole. With this settings, the beam was numerically transported through the system with minimal emittance growth. Manufacturing of the septum system has started.

INTRODUCTION

The ExB chopper system in the LEBT section of FRANZ consists of a dipole magnet and a pulsed electric deflector. The fields are oriented in a Wien filter configuration. During the flat top of the HV pulse of the electric deflector, the electric deflection of the beam compensates the magnetic deflection and the beam is transmitted in forward direction. Between two deflector pulses, i.e. when the deflector voltage is zero, the beam is deflected about 10 ° by the dipole magnet. To minimize the energy deposition of the beam on the vacuum chamber walls without increasing the magnetic field on the beam axis, a following septum magnet is under construction. During the rise and fall of the deflector voltage pulse the beam sweeps between the full field region and the zero field region of the septum magnet and forms the required pulsed beam. To minimize secondary particle emission during the deflector pulses, the possibility of using a massless septum system was investigated [3]. The most promising design regarding longitudinal and transversal magnetic field distributions on the transmitted beam axis is shown in Fig. 1. Table 1 shows the current specifications.

The C-magnet is tilted 12 ° to match the deflection angle of the deflected beam and to further reduce the magnetic field on the transmitted beam axis. To minimize beam losses, the pole shoes were modified with additional fittings, so that the deflected beam is exposed longer to the maximum magnetic field in the gap. With this fittings the C-magnet will deflect the beam into a beam dump, while the shielding tube made of high permeable material (VACUFLUX 50) will shield the 60 mm distant beamline of the transmitted pulsed beam from the fringing field of the C-Magnet (see Fig. 2). The varying proportions of the tube along the beam axis, particularly the widening at the ends, serve a more effective shielding of the magnetic field. A slit on the side assures a lossless beam sweep during the rise and fall of the deflector pulse.

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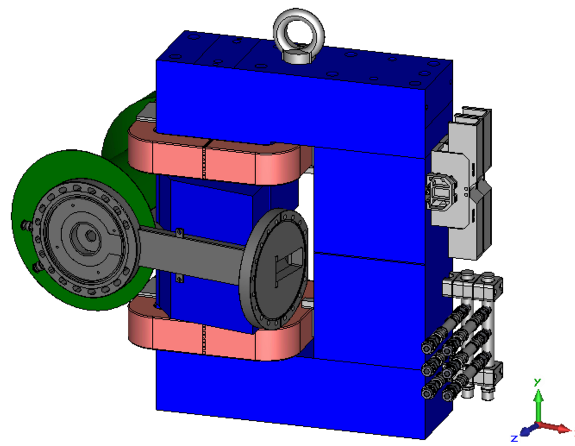

Figure 1: Model of the massless septum system for the FRANZ LEBT, consisting of a C-magnet and a shielding tube.

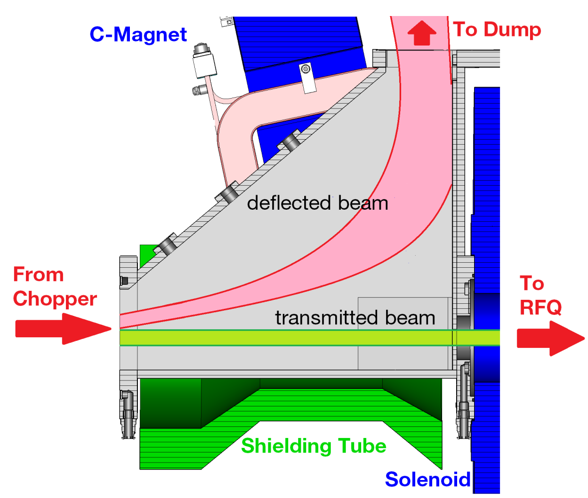

Figure 2: Horizontal cross section of the septum system including the vacuum chamber. The C-magnet will extract the deflected beam out of the beamline and guide it into a beam dump. The shielding tube will reduce the magnet's fringing field on the beam axis of the transmitted beam.

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Table 1: Specifications of the Septum System

C-Magnet	
Height	620 mm
Width	460 mm
Length	150 mm
Dipole Gap	45 mm
Vertical Yoke Width	200 mm
Horizontal Yoke Width	122.5 mm
Tilt	12 °
Distance to Tube	7 mm
Coil Current	93 A
Turns	2 x 48
Shielding Tube	
Length	375 mm
Outer Diameter	Min: 160 mm; Max: 280 mm
Inner Diameter	Min: 80 mm; Max: 178 mm
Distance to Repeller	45 mm
Distance to Solenoid 3	41.5 mm

MAGNETIC FIELD DISTRIBUTION

The numerical simulations of the magnetic fields were done with *CST EMS* [4]. Figure 3 illustrates the functional principle of the massless septum system: if the shielding tube is close enough to the C-magnet, the magnetic resistance decreases locally and part of the magnetic flux flows through the shielding tube, so that the fringing field on the respective side of the magnet is suppressed.

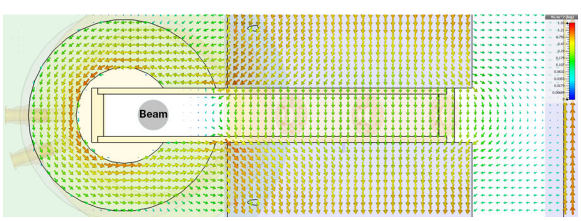

Figure 3: Transverse section of the septum system. Magnetic field lines visualize the magnetic flux.

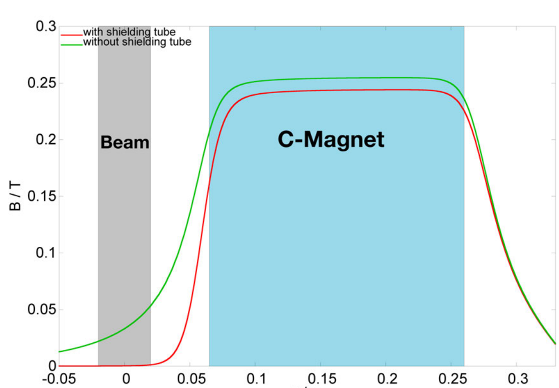

Figure 4: Magnetic field in the dipole gap with and without shielding tube.

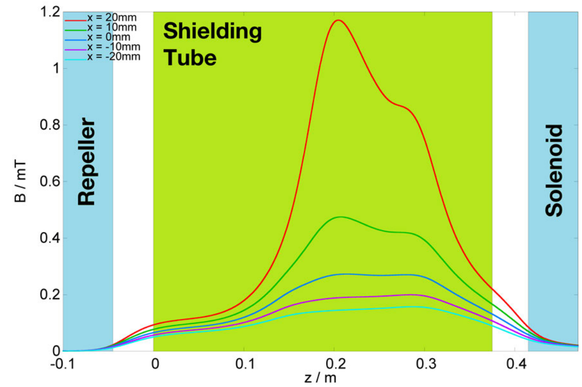

Figure 5: Magnetic field along the beam axis for different horizontal off-sets. Within 40 mm, the magnetic field increases by a factor of 10.

The longitudinal and transversal positioning of the C-magnet and the shielding tube as well as the coil current were optimized for minimal magnetic field on the beam axis of the transmitted beam and minimal losses of the extracted beam in the vacuum chamber for the proton beam used for FRANZ [5]. For basically all parameters, a reduction of the field resulted in the increase of the losses and vice versa, so that a reasonable compromise had to be made. Especially the distance between the magnet and the tube turned out to be an influential and sensitive parameter, as it determines the coupling of the magnetic flux between the two components of this septum system. If the distance between the shielding tube and the C-magnet is too long, the fringing field on the beam axis will be too high. If the distance is too short, it will result in a magnetic short circuit and the main dipole field will decrease significantly. For the optimized setting, the magnetic field in the gap is only slightly decreased (see Fig. 4).

Figure 5 shows the magnetic field on the beam axis. One can see an inhomogeneous field distribution within the beam. Towards the magnet the magnetic field increases rapidly. The field maximum is at the location of the smallest distance between the tube and the magnet.

Furthermore, the design of the C-magnets and the pole shoe additions were optimized to further minimize the losses of the extracted beam in the vacuum chamber. By matching the design to the dynamics of the extracted beam, the effect on the transmitted beam could be kept to a minimum.

With a maximum deflection field of 244 mT in the gap, the maximum field on the transmitted beam axis is reduced from 33 mT without shielding tube to below 0.3 mT with shielding tube.

BEAM DYNAMICS

Figure 6 shows a beam transport simulation of a 120 keV, 50 mA proton beam from the chopper to the RFQ with the Particle-In-Cell code *bender* [6]. Between the deflector pulses and without the septum system, the beam is lost in the vacuum chamber. Even with septum system, there are still some losses due to the slight broadening of the beam by

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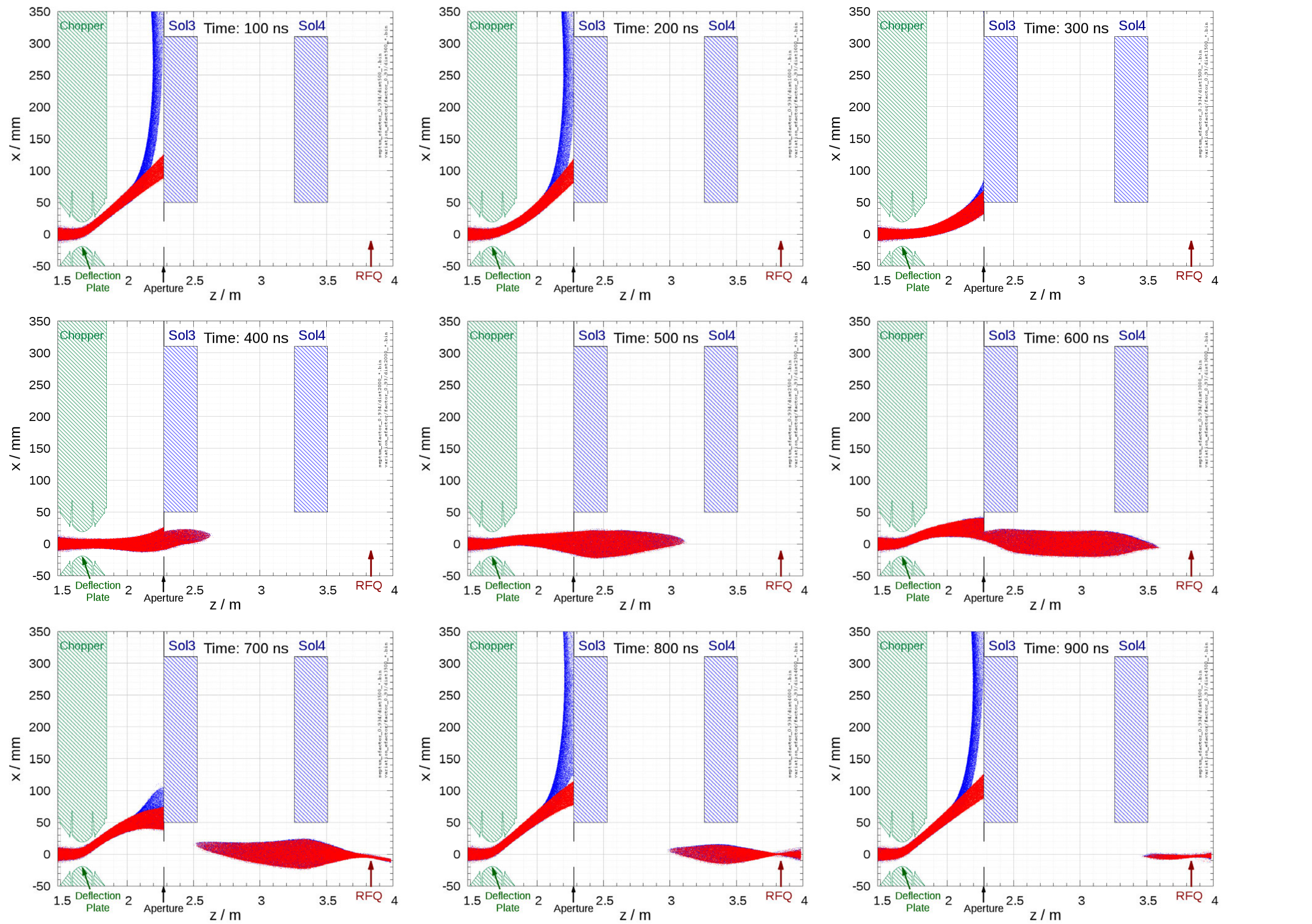

Figure 6: Sweep of the 120 keV, 50 mA proton beam during the HV pulse of the chopper's electric deflector, with (blue) and without (red) septum system [3].

the C-magnet. This is due to the fact that the beam enters the gap of the magnet partially at the edge, so that a part of the beam is initially only deflected by the fringing field. Efforts of keeping the losses at a minimum led to a slight overdeflection of the extracted beam.

At the flat top of the deflector pulse, the beam transport with and without the septum system is almost identical. By adjusting the fields of the chopper system slightly, the beam were transported with minimal increase of emittance growth and matched into the RFQ [3].

CONCLUSION AND OUTLOOK

In numerical simulations the fringing field of a C-magnet could be sufficiently decreased by a magnetic shielding tube, so that a system of both can be used as a massless beam separation system. The C-magnet was designed and manufactured. The design of the shielding tube will be further optimized to minimize the field on the beam axis and decrease the losses of the extracted beam. Manufacturing of the tube will start thereafter.

REFERENCES

[1] C. Wiesner et al., "Chopping High-Intensity Ion Beams of FRANZ", LINAC2014, Geneva, September 2014, WEIOB01 p. 765 (2014).

[2] O. Meusel et al., "FRANZ-Accelerator Test Bench And Neutron Source", LINAC2012, Tel-Aviv, September 2012, MO3A03 p. 130 (2012).

[3] C. Wiesner, "Chopping and Transport of High-Intensity Ion Beams", PhD Thesis, University Frankfurt am Main, Germany, 2014.

[4] Computer Simulation Technology, Darmstadt, Germany, www.cst.com

[5] O. Payir, "Strahlseparationssystem für intensive Ionenstrahlen", Bachelor Thesis, University Frankfurt am Main, Germany, 2014.

[6] D. Noll et. al, "The Particle-In-Cell Code *bender* and it's Application to Non-Relativistic Beam Transport", HB2014, East-Lansing, MI, USA, November 2014, WEO4LR02 p. 305 (2014).