Magnetic Septa for the SIS100 Accelerator at FAIR

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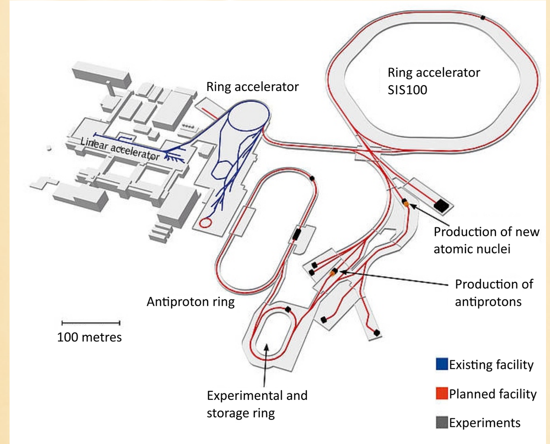
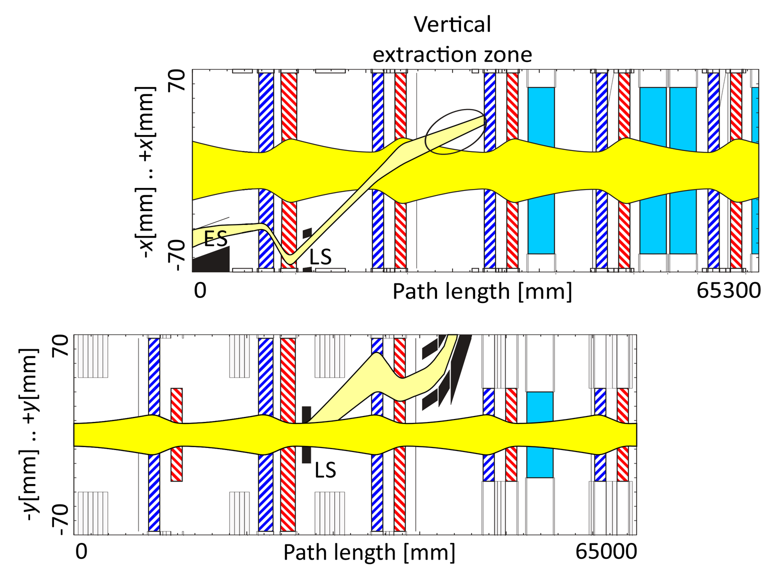


Introduction

The future heavy ion synchrotron SIS100 will use magnetic septa for the injection and the extraction lines. Due to limited space and increased need of components, the septa have to be pushed against the limits. The synchrotron requires a base vacuum that can only be achieved by baking all warm components, including the septa.

There will be two extraction schemes, fast single-turn extraction and slow extraction. The latter is started by six Resonance Sextupoles distributed around the ring. It employs two Lambertson-type septa: one matching the kickers, the other for bending the extracted beam on the main direction again.

Slow Extraction Scheme



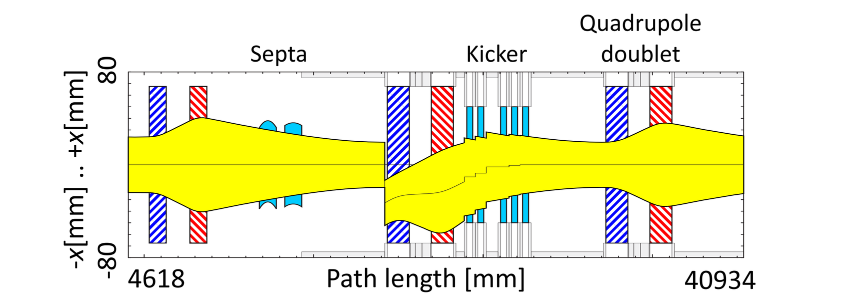
ES: Electrostatic septum
LS: Lambertson septum

Good practice limits

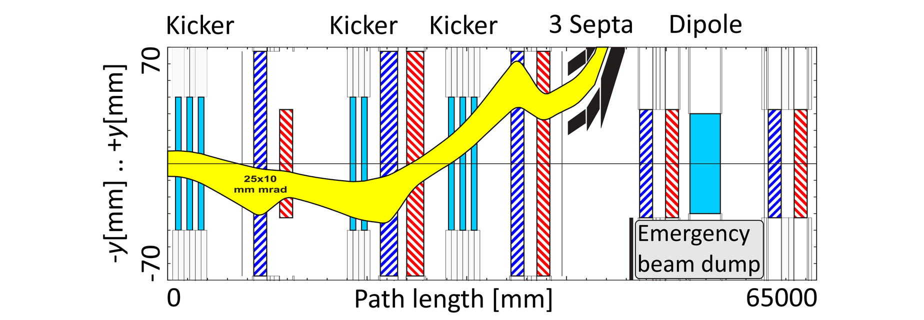
Current density	≤ 100 A/mm^2
Cooling channel diameter	≥ 3 mm
Conductor wall thickness	≥ 1 mm
Water velocity	≤ 10 m/s
Reynold number	≥ 2500
Water temperature rise	≤ 40 K

- The injection septa these days enter manufacturing phase at Danfysik
- Some details of the extraction line still are in discussion

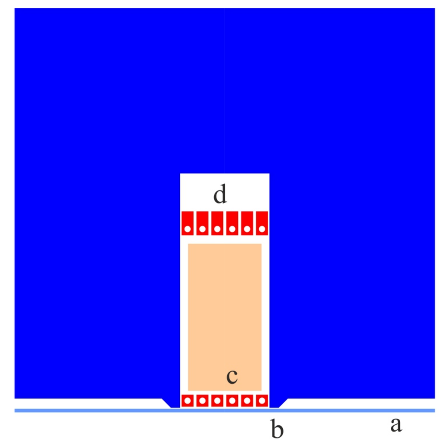
Injection Scheme (horizontally)



Fast Extraction Scheme (vertically)

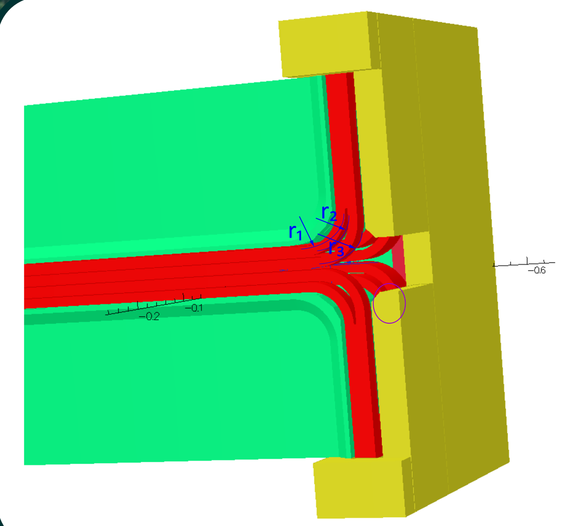


Optimising Field Quality



2d Optimisations

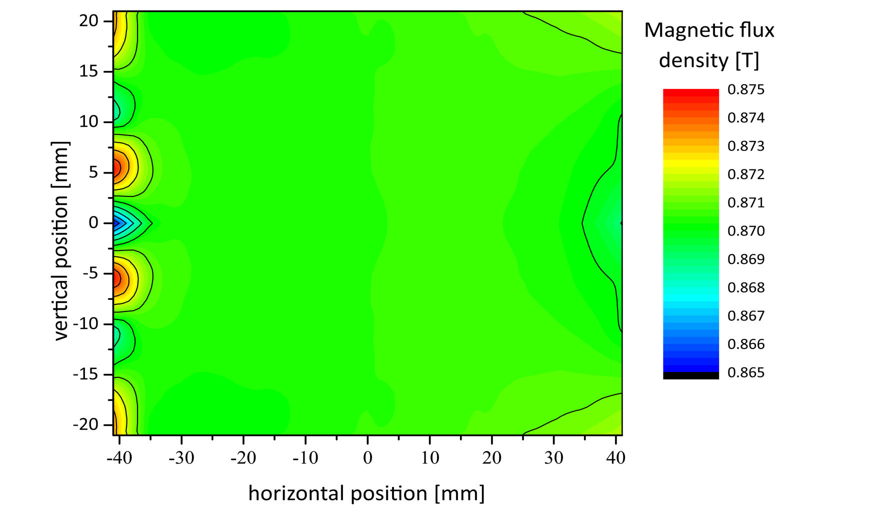
- Distance *d* between outmost turn and yoke
- Distance *2d* between turns
- Magnetic screen (a) against orbit
- Small gap (b) between yoke and screen over small area only
- Reinforced coil in backleg (d)
- Every turn as single wire without soldered joint to cooling channel



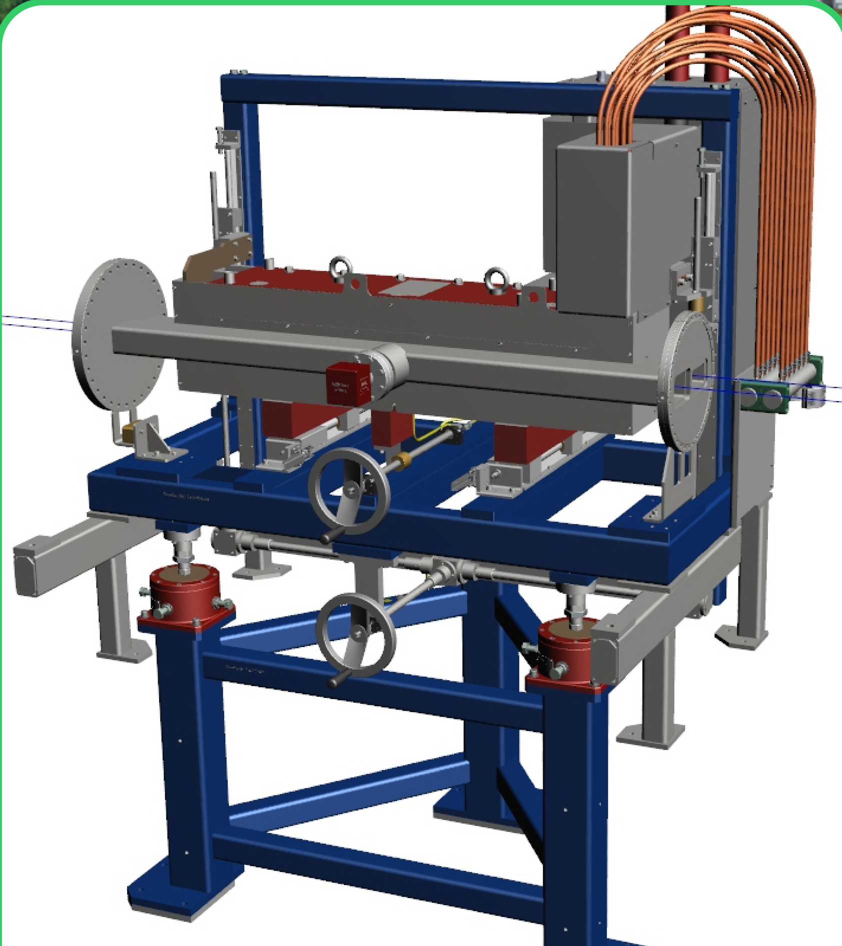
3d Optimisations

- Symmetric coil setup for stronger septa
- Combined optimisation of Rogowski radius r_1 and coil bending radii r_2 and r_3
- Chamfer at the inner side of the shield
- Curved septum for larger bending angles to suppress sextupole error

Field Quality



Integrated flux density $\int B_y\,dz$ in the extraction region of Injection Septum 1 from simulation

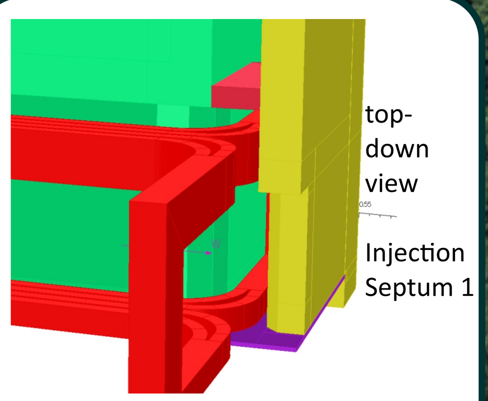


Model of Injection Septum 2

Extraction

Injection

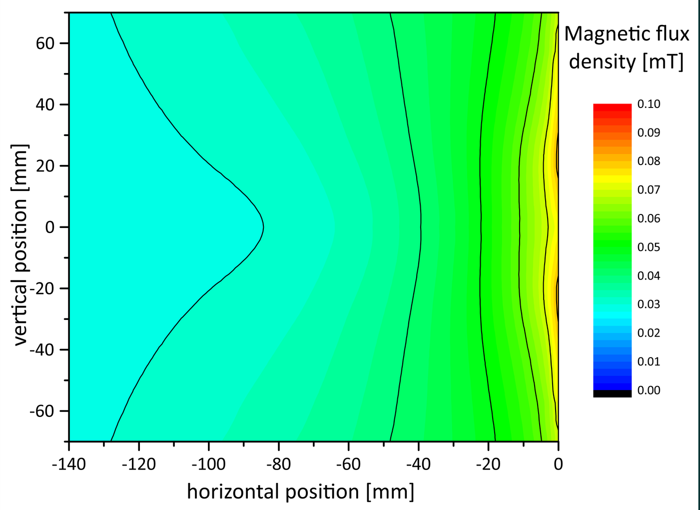
Stray Field Suppression



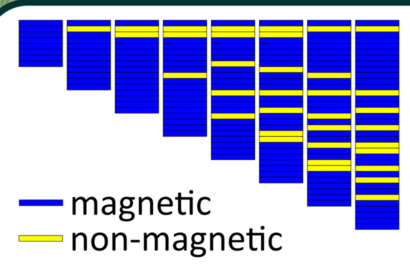
Suppressing stray field with
- magnetic screen as thick as possible between beams
- thick yoke
- end shield close to yoke
- guiding plate above coil

Other concepts like iron plates following the coil were bad for field homogeneity.

Field Quality



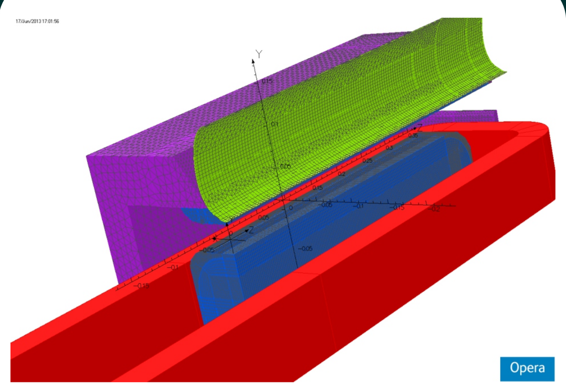
Integral stray flux density $\int \sqrt{B_x^2+B_y^2}\,dz$ in the orbit region for Injection Septum 1 as simulated. It is in the order of earths magnetic field, but not as homogeneous.



In septa with thick magnetic screens, additional non-magnetic layers help to increase efficiency.

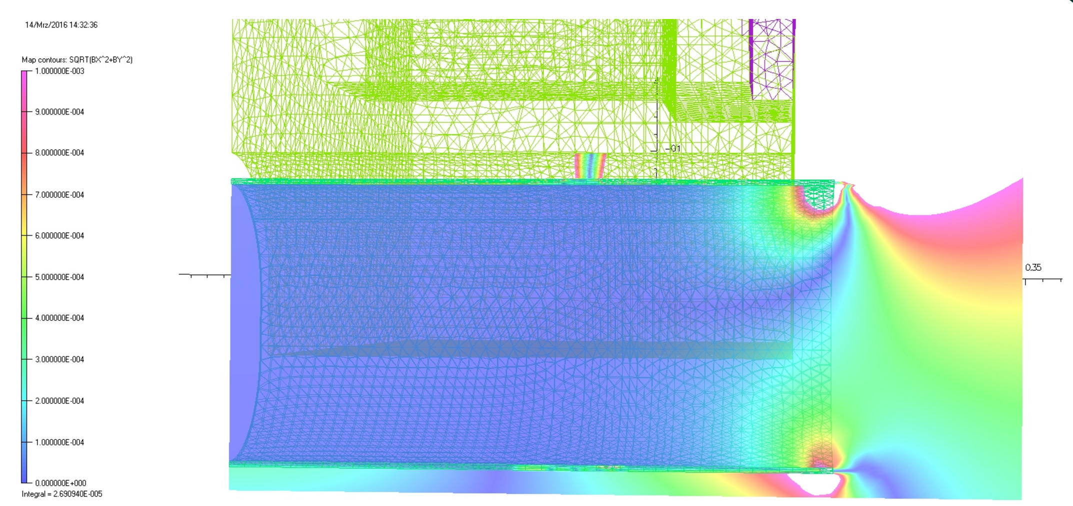
Here shown are ideal distributions for different screen setups with 1 mm individual layer thickness for Extraction Septum 3.

Lambertson-Type Septa

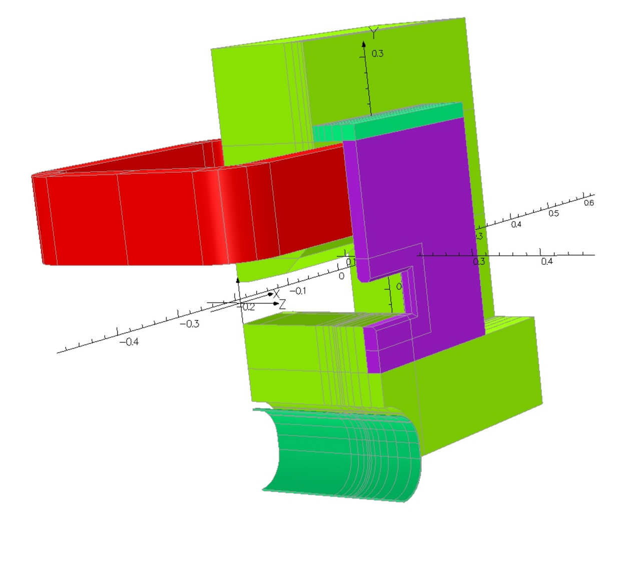


Lambertson Septum

Design parameters and ideas:
- Thin blade (6 mm)
- Deducted from H-type dipole
- Racetrack coil for easy winding and more freedom in design
- Pole sizes differ for better field
- Thin shield around orbit tube
- Yoke between beams has to be one piece for field quality, and therefore has to be bakeable
- End shields as normal septa
- Rogowski profiles at the sides and at the ends



Stray field in the Lambertson septum (seen from top). The shield is working well, but the ends cannot be protected within building frame. This holds for all septa presented here.



Lambertson Steerer

Had to be introduced very late in the system layout process. Thus, it had to be short at almost any cost.

The top pole nearly exclusively consists of Rogowski profile. It has twice the normal radius, because the bottom pole is flat and acts as a magnetic mirror.

As a speciality here, it has been shown by simulation that the backleg may have a hole of 10 cm diameter for installing a pump to the extraction line.

Further Concepts and Ideas

Things that have been or are being discussed include:
- Integrate the baking jacket into the magnet. Avoids huge mechanical problems, introduces huge thermal problems.
- Put the septum in vacuum. Intriguing for thinner septum blade, but challenges for vacuum, baking, and installation space.
- Superconducting septum. At least will need a lot of time.
- Integrate septum and steerer. Failed due to bad field quality once the steerer is on ($\Delta B/B \approx 10\%$).
- Replace the integrated steerer by a mechanically rotated septum. Mechanically challenging, blade thickness reduced.
- Replace one septum with integrated steerer by two septa at an angle to each other. Exceeds 2T limit for normal-conducting magnets.

Summary

The magnetic septa of SIS100 are based on standard models but employ a range of special considerations to achieve a good field quality and to meet safety requirements. The septa for injection are on the way to be build, and it is expected to put the extraction septa for tender during next year.