Optimising a Magnetic Septum with Heating Jacket

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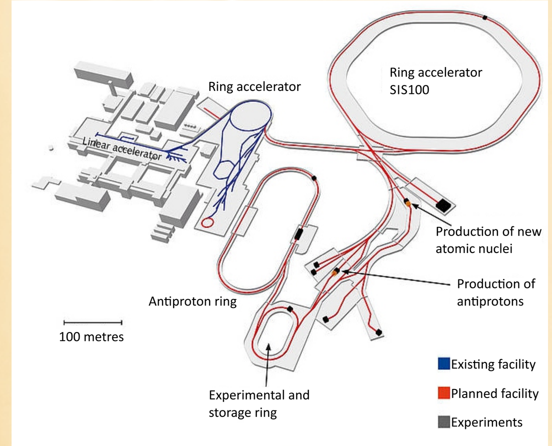


Introduction

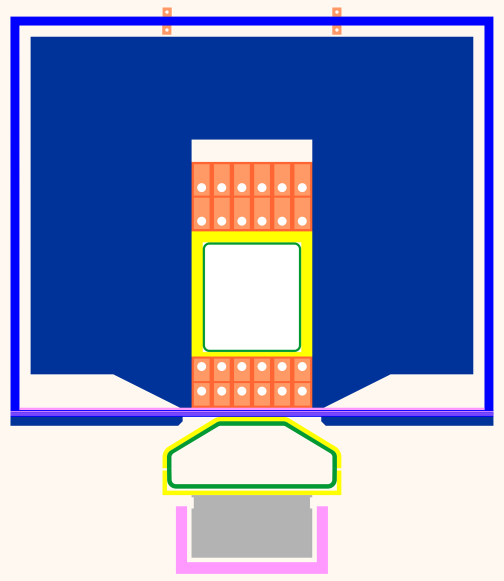
The extraction line of the future synchrotron SIS100 will have a series of three normal-conducting magnetic septa which deflect the beam upwards. Underneath the third septum, there will be a beam stop for emergency extraction. Therefore, the entire region will be activated with anticipated doses that forbid manual installation of a heating jacket. A mechanism which would automatically open this third septum and install a heating box proved too big during mechanical design studies.
Therefore it has been decided to include the heating jacket into the septum. This significantly reduced available space for the magnetic screen to protect the orbit region from stray field.

Parameters Magnet

Parameter	Septum 3	Limit
Deflection:	upwards	
Flux density:	1.85 T	
Aperture width:	80 mm	
Min. septum blade thickness:	49 mm	
Current density (blade, av.):	85 A/mm²	
Current density (max.):	101 A/mm²	≤100 A/mm²
Water velocity:	9.2 m/s	≤10 m/s
Water pressure:	6.3 bar	≤10 bar
Temperature rise:	40 K	≤40 K
Vacuum baking temperature:	200 ... 250 °C	

This hydro plant could serve two of these septa

Legend:
- magnetic steel
- nonmagnetic spacer
- copper
- insulation
- vacuum chamber
- baking jacket
- beamstop



Initial ideas

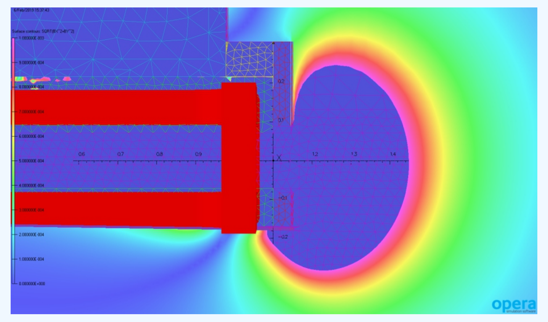
The idea of integrating the baking system into the magnet was the notion that very thin foil heating elements would suffice. This is clearly not the case as the real problem is not heating itself but maintaining the temperature difference between inside and outside. This requires some sort of heat insulation which is hard to miniaturize.

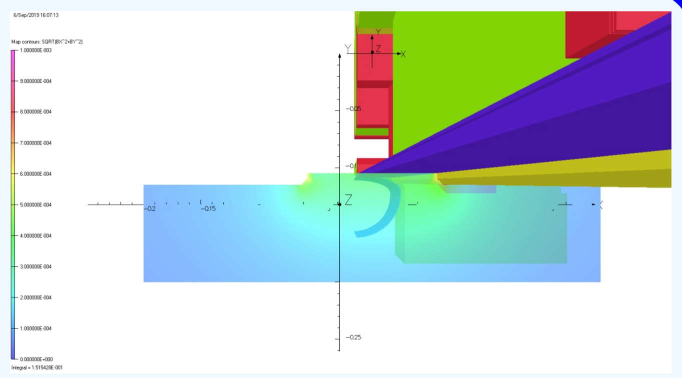
A change of perspective

In most magnets with built-in heating jacket, the problem is to have sufficient insulation to keep coil and yoke cool. In the case of a magnetic septum, cooling power is more than sufficient. The insulation therefore may be thinner than usual, but at the expense of energy directly lost to the cooling system.
As the temperature distribution does not change, it should not be a problem to provide the higher current.

Sources of stray field

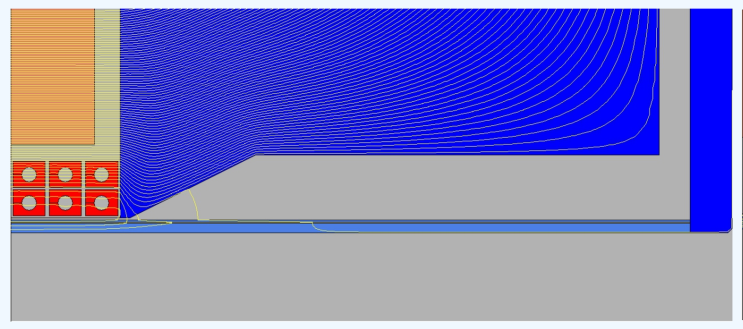
- leakage through magnetic screen
- leakage from yoke
- field at the ends of the magnet



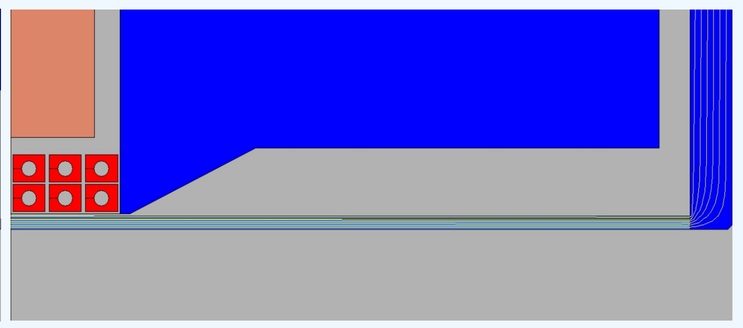


Colour range 1 mT

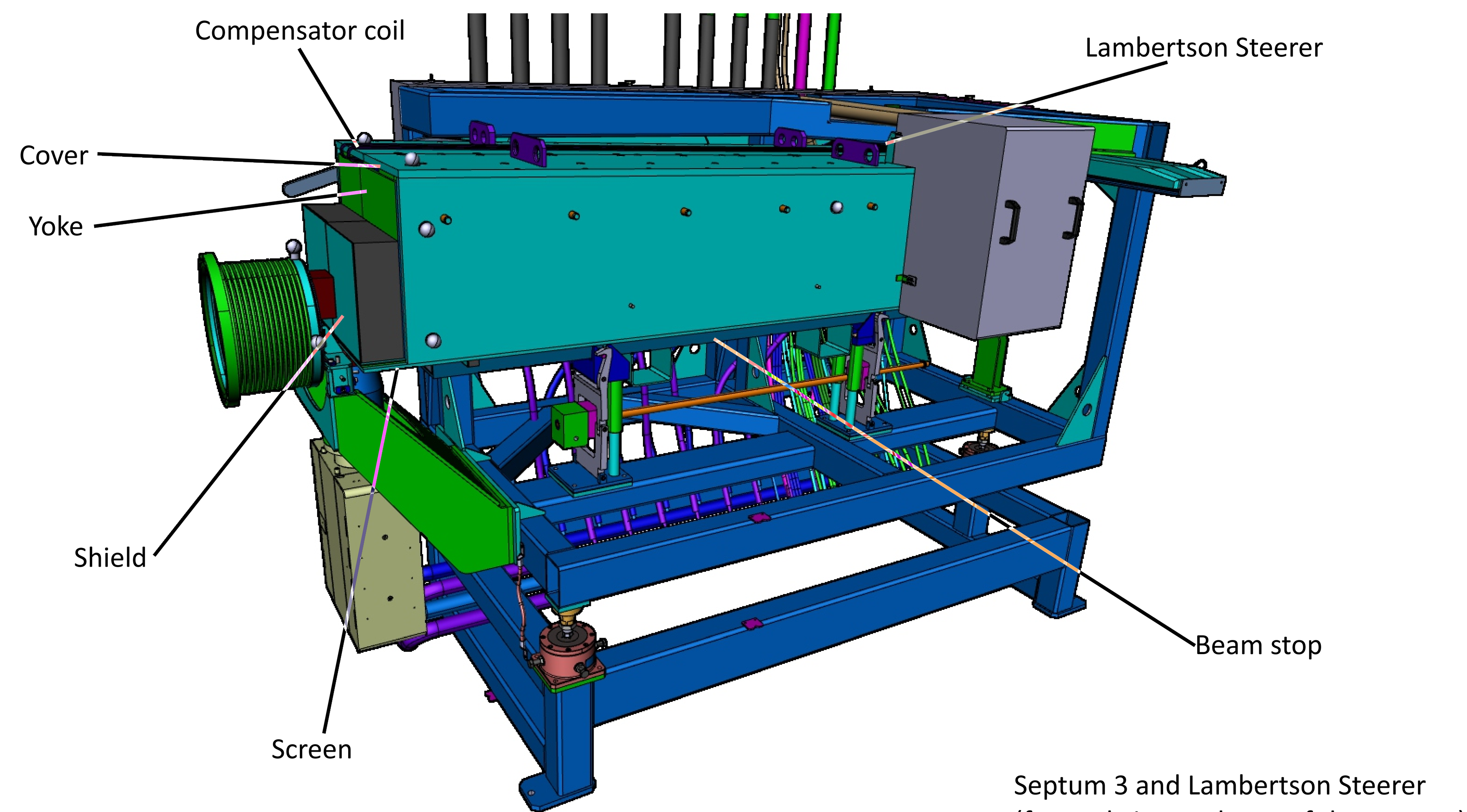
Compensator Coil



During operation of the septum, a few field lines pass through the magnetic shield, which then becomes saturated.



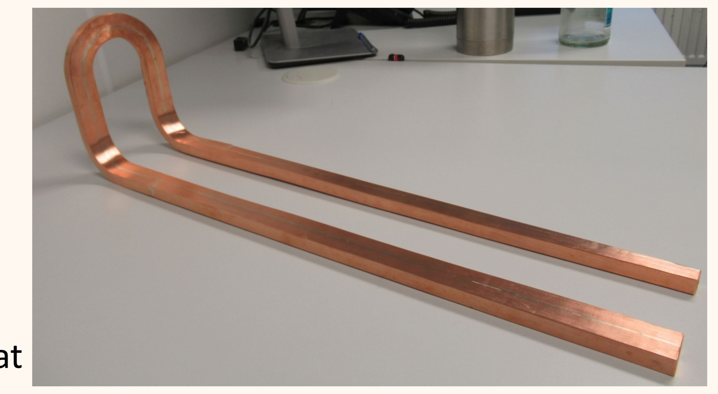
The compensator coil creates a field in the magnetic shield which is oriented opposite to the field generated by the main coil.



Septum 3 and Lambertson Steerer (formerly integral part of the septum) on a common stand

Optimisation measures

- Only ground insulation, spacers between conductors
- Custom-made wire, as standard formats lead outside parameter window
- Thin magnetic screen with optimised spacers
- Wedge-shaped conductors reduce overall heat load



Test soldering of a piggyback conductor. Wedge shaped conductor in background.

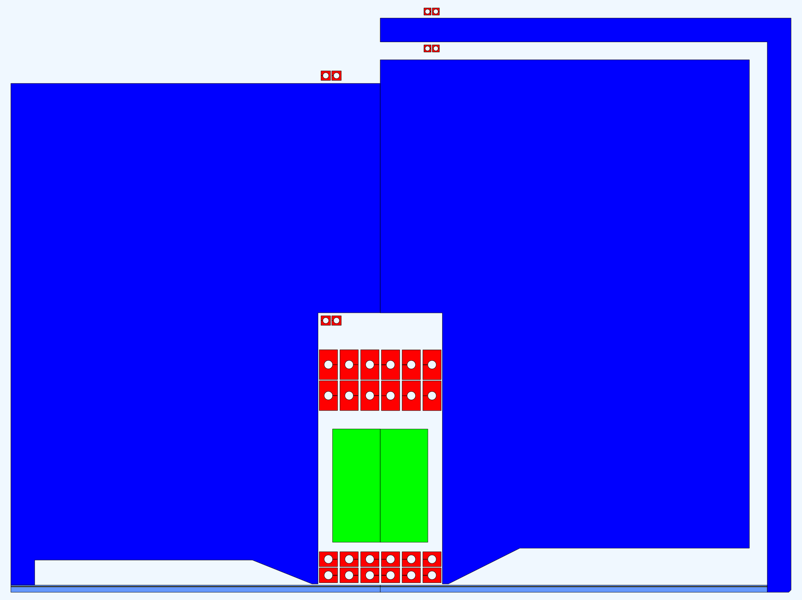
Advantages / Disadvantages

+ No mechanical parts necessary
+ Reduced height (SIS300, another synchrotron, planned atop)
− Energy loss during baking due to reduced heat insulation
− Energy loss due to increased gap width
− Reducing stray field is a challenge

Crazy Ideas

- Maintain temperature difference by Peltier effect
- Implement radiator inside cooled vacuum chamber and hope for photons to remove adsorbed material from chamber interior (in operation at CERN?)
- Orbit vacuum tube from magnetic iron. This would be a bimetal strip while baking.

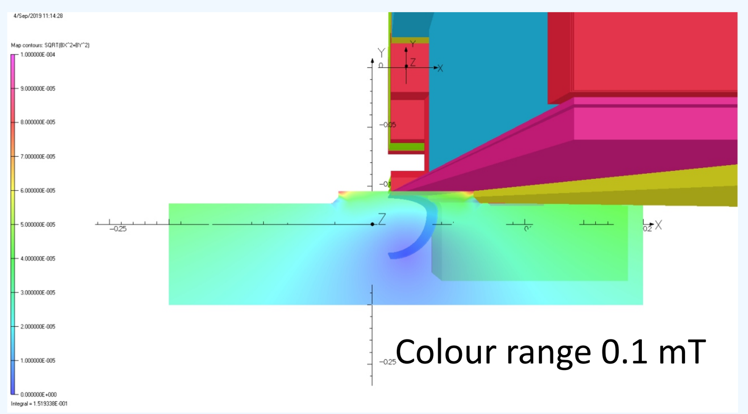
Against leakage from yoke



In earlier models, the compensator coil has been directly wound around the yoke. This has the disadvantage that the end cover shortcuts the field lines. Additionally, the yoke had to have a link to the magnetic screen. With the compensator coil wound around the cover, both problems are solved.

The cover (right) catches field lines which escape from the yoke.

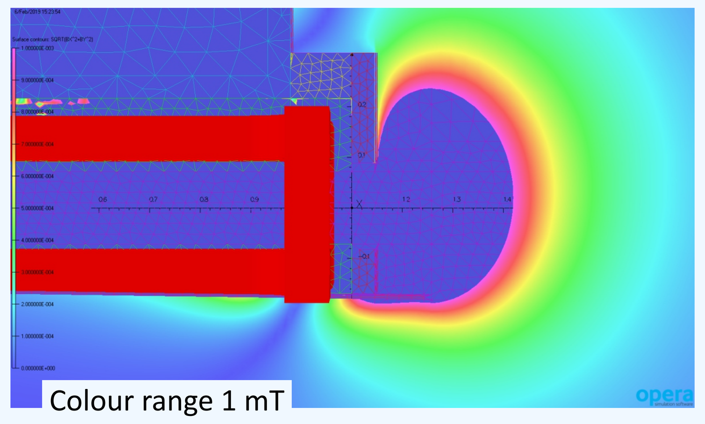
Effect of compensator coil



Colour range 0.1 mT

Note the screen reinforcement (yellow). It reduces saturation outside the region where field lines of the main and compensator coils cancel.

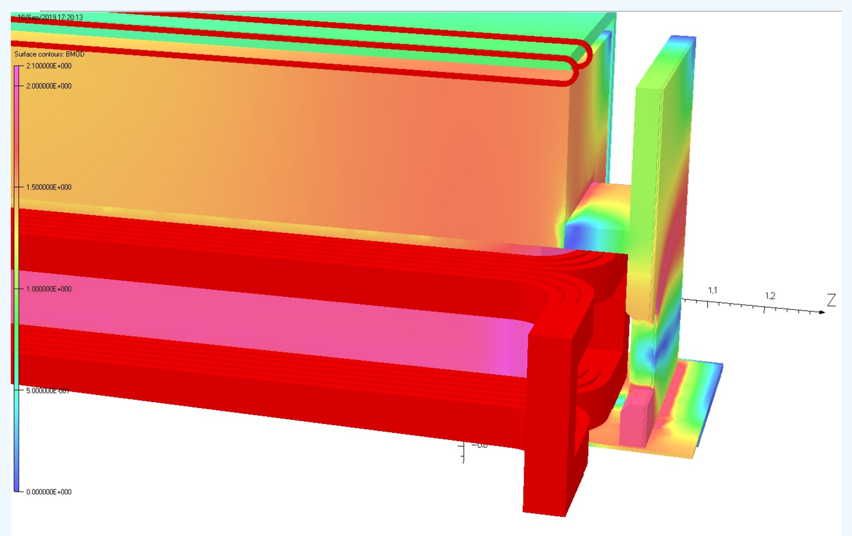
Extension of magnetic screen



Colour range 1 mT

This extension of the magnetic shield is quite effective, but it collides with other components. Thus it will be the final measure if required.

Shield for coil end



A box around the coil end catches most field lines going through the end of the coil and guides them back into the upper part of the yoke.

What about field homogeneity?

This is not a problem as the baking jacket increases the distance between good-field region and poles and coils.

Conclusion

Integrating a baking jacket into a septum is only possible for rather large distances of the orbit and the extracted beam. We propose a solution which still has reasonably low stray field.

The baking jacket leads to energy losses in two aspects:
First, the gap becomes wider (higher), thus requiring more Ampere turns. Second, the thermal insulation is thinner than optimal, thus requiring the coil to be actively cooled. The higher heat current is another energy loss during baking.