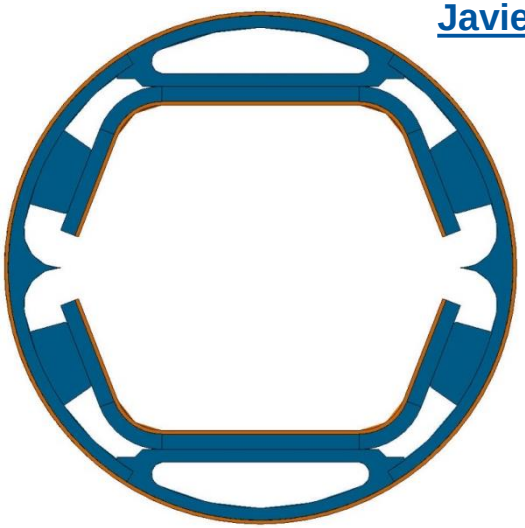

CERN

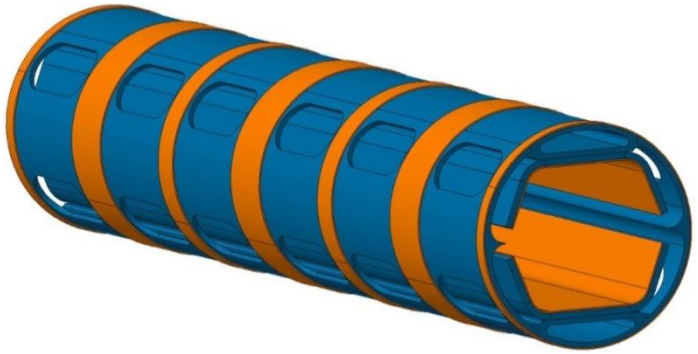
FCC-hh beam screen design

EuroCircol WP4 meeting, Geneva

Javier Fernandez Topham[1], Cedric Garion[2]

(1) CIEMAT, (2) CERN





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EuroCirCol
A key to New Physics

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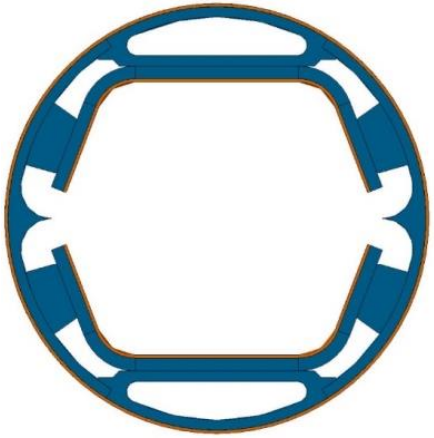
Outline

- Beam screen design
  - Beam screen evolution
  - Beam screen geometry
- Mechanical behaviour
  - Quench analysis
- Thermal management
  - Temperature profile
  - End dipole absorber
  - Heat transferred to cold bore
- Conclusions
- Next steps

Beam Screen Design

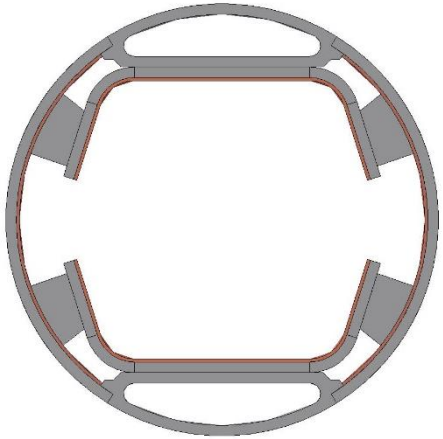
Beam screen evolution

Berlin 05/2017
FCC week

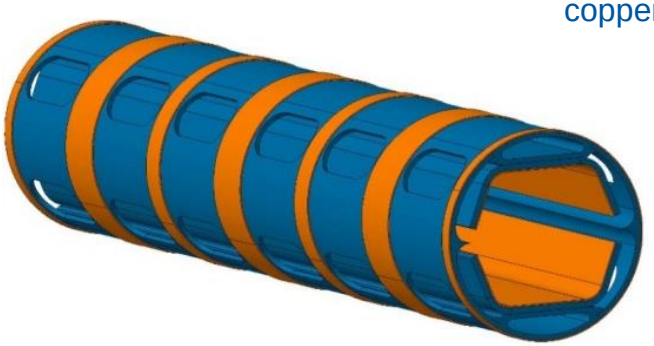


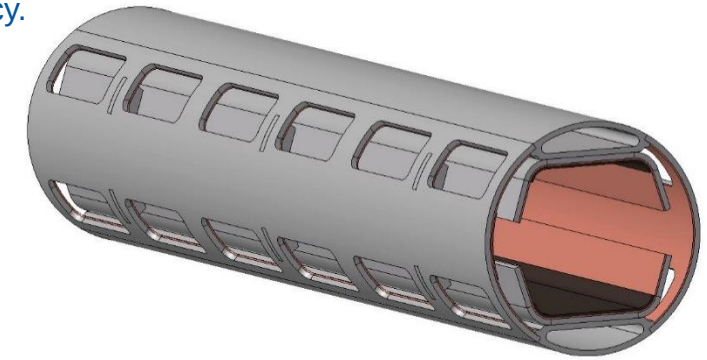
1. Reflectors have been changed by an co-laminated copper coating and sawtooth synchrotron radiation absorber.

Geneva 10/2017
WP4 meeting



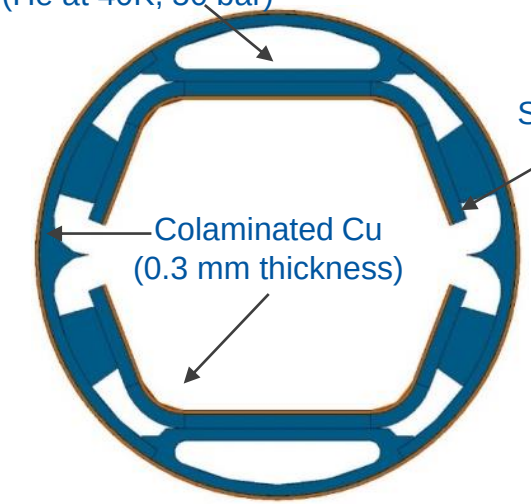
2. Copper strips have been eliminated since copper coating increases thermal efficiency.

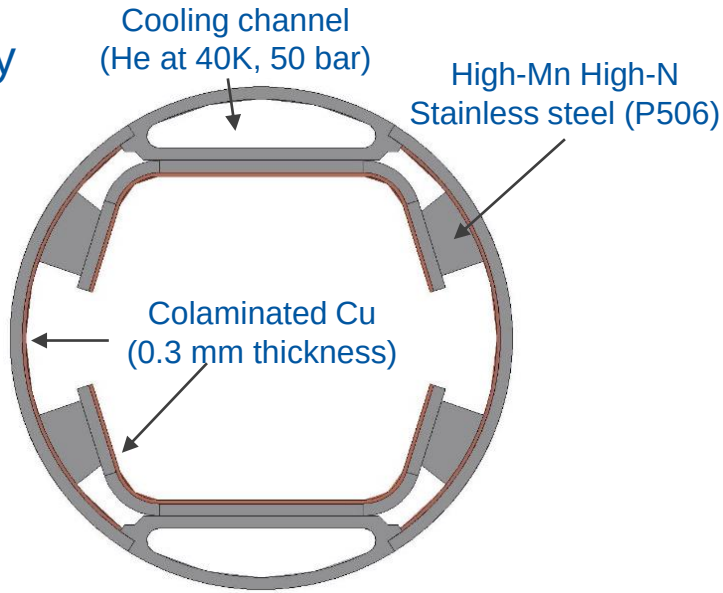


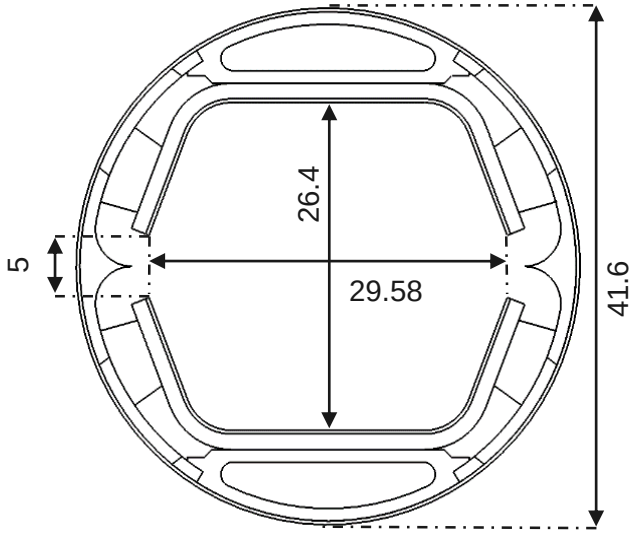


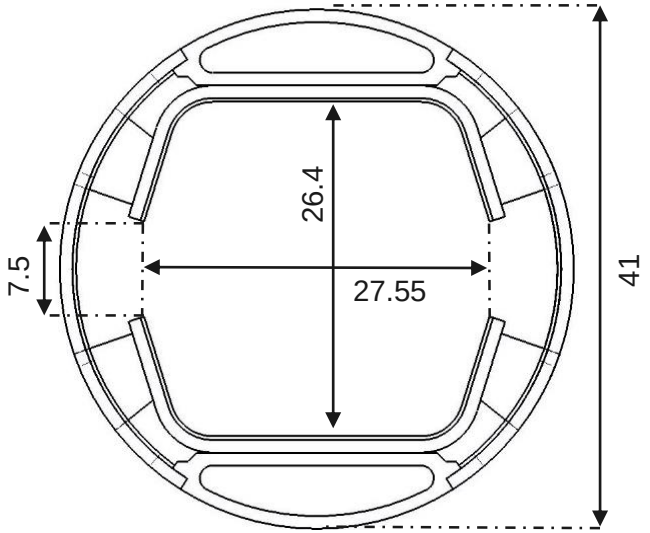
Beam Screen Design

Beam screen geometry



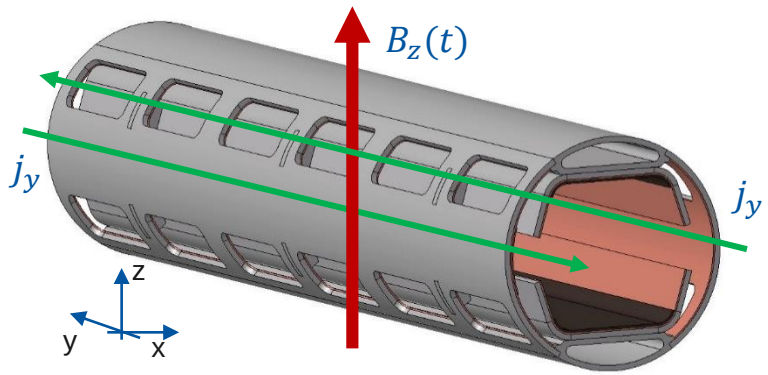






Mechanical Design

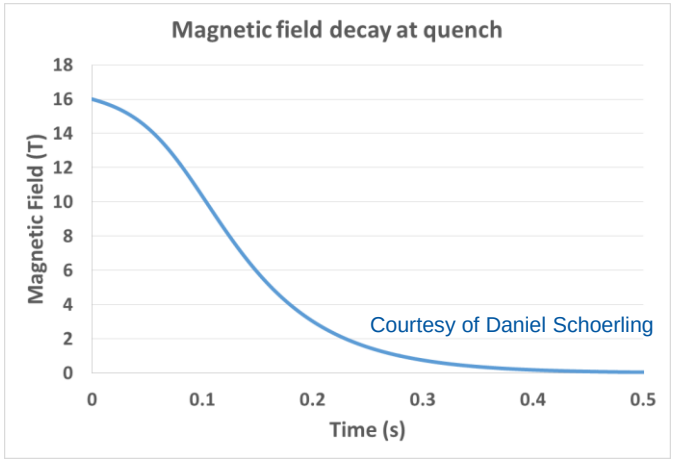
Magnet quench

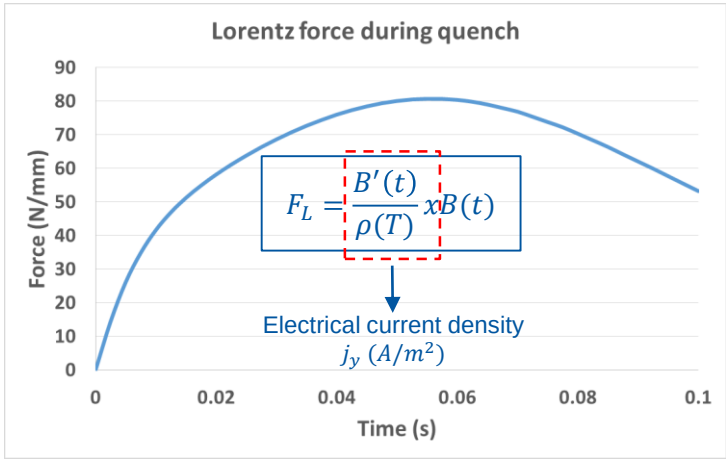


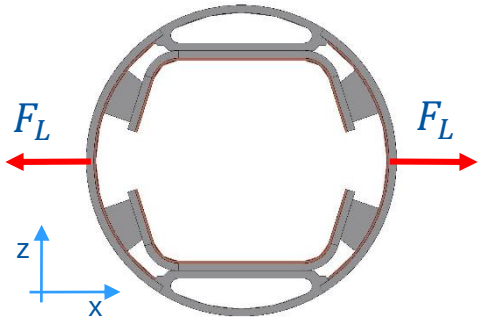
Variation of magnetic field at quench produces currents all along the beam screen.

These currents produce Lorentz forces that have to be correctly withstand by the beam screen.

This 3D simulation has been carried out taking into account 'Joule effect' coupling magnetic field and temperatures ($\rho C_p \frac{\partial T}{\partial t} - \nabla(k\nabla T) = Q_e = JE$).

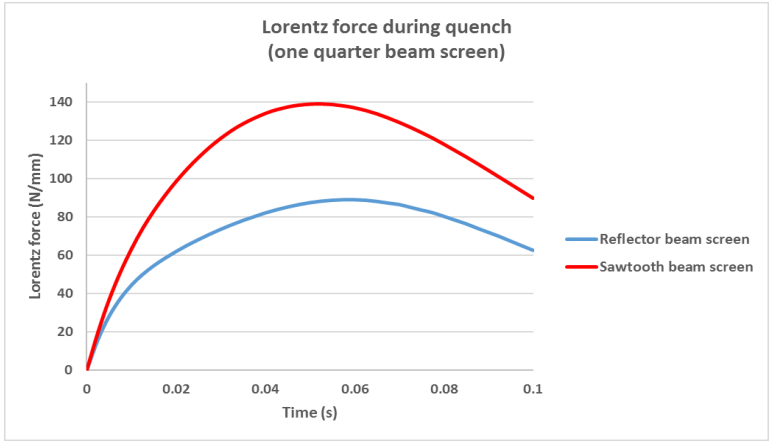


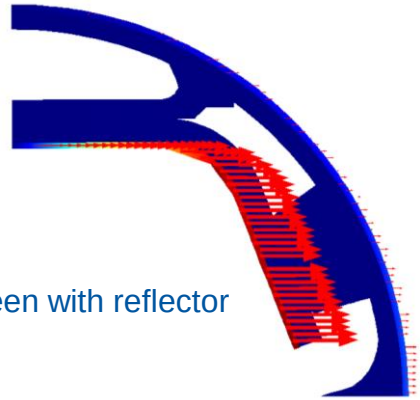




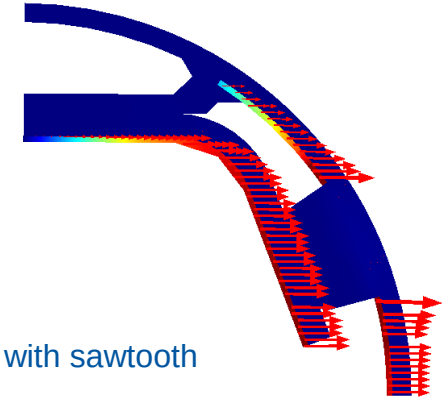
Mechanical Design

Lorentz forces

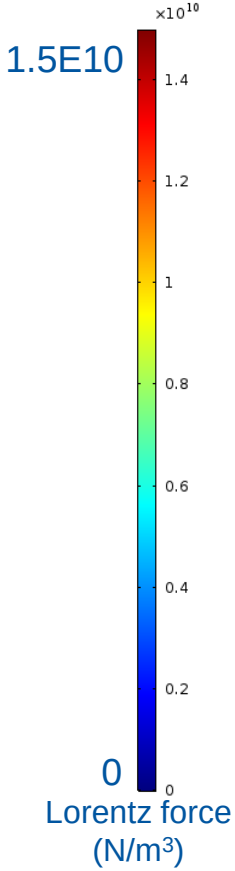




Beam screen with reflector



Beam screen with sawtooth

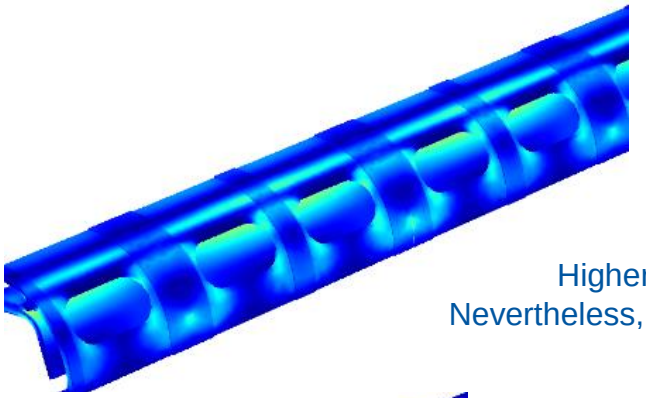


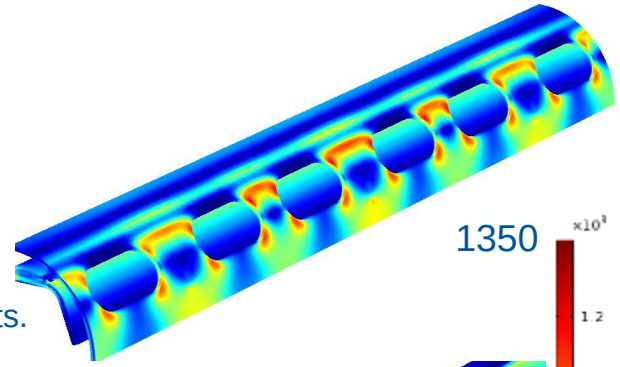
New copper part increases 57% Lorentz force.

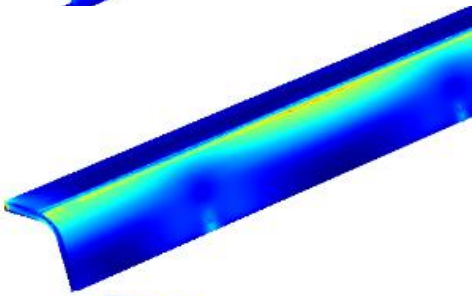
High copper electrical conductivity produces more induced currents, thus, more Lorentz force during quench.

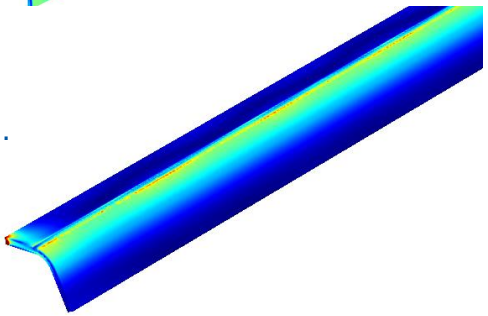
Mechanical Design

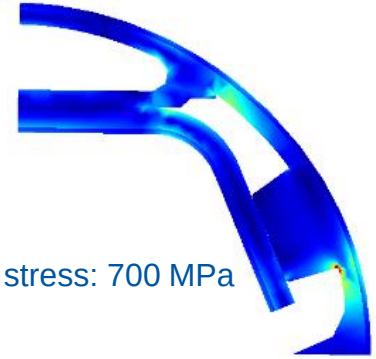
Stress analysis

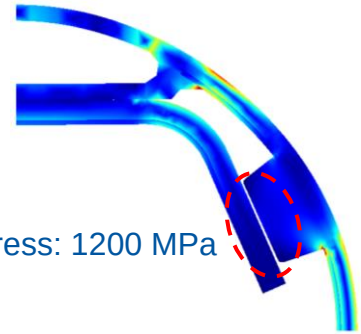












Higher stress with new co-laminated copper.
Nevertheless, plasticity was not reached in any of its points.

Welding lines must be studied in detail to ensure its strength.

Bigger displacements provoke eventual separation between stiffeners and inner chamber.

Max stress: 700 MPa

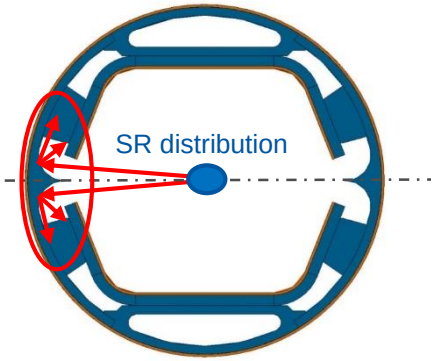
Max displacement exterior beam screen: 0.35 mm

Max stress: 1200 MPa

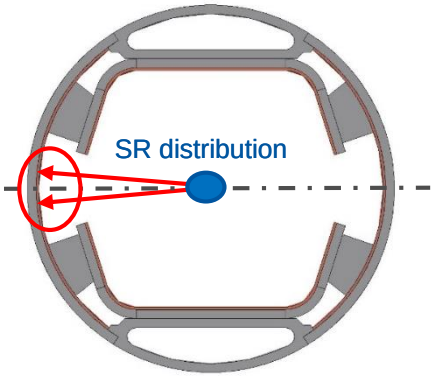
Max displacement exterior beam screen: 0.6 mm

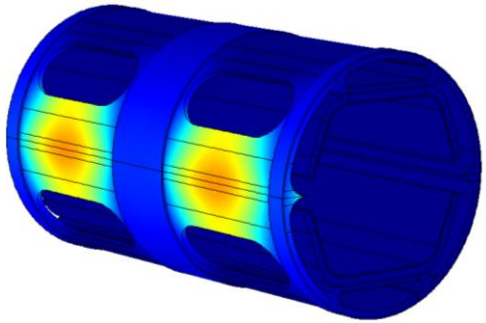
Thermal analysis

Synchrotron radiation impact

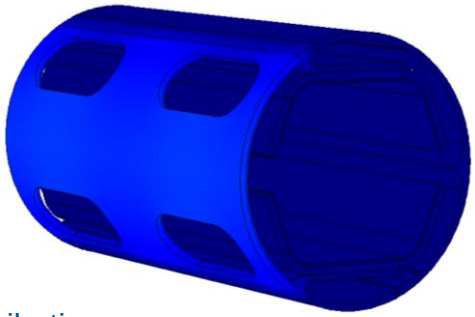


SR distribution changes with sawtooth.
Different heat load.

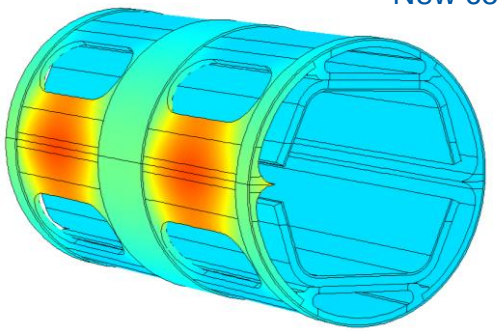




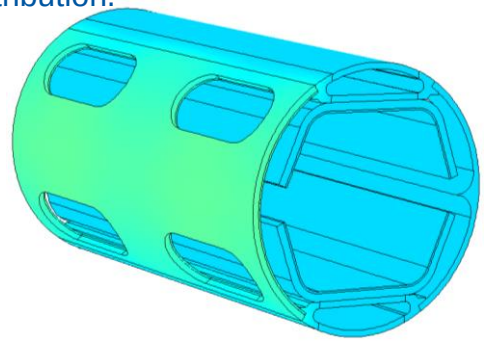
Helium inlet conditions
40 K, 5000 W/m^{2}K, 50 bar



New copper layer produces different temperature distribution.

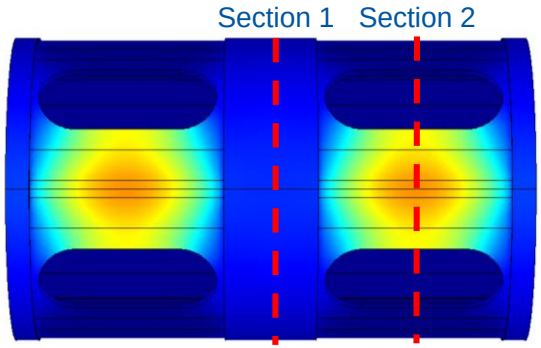


Helium outlet conditions
57 K, 5000 W/m^{2}K, 50 bar



Thermal analysis

Synchrotron radiation impact



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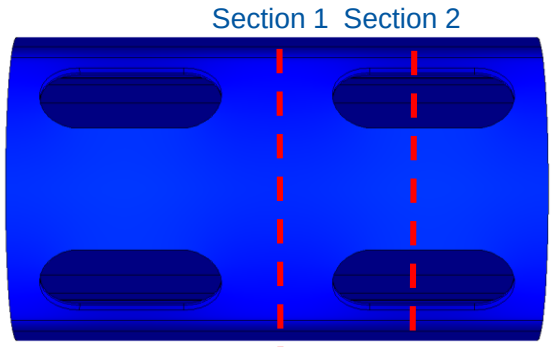
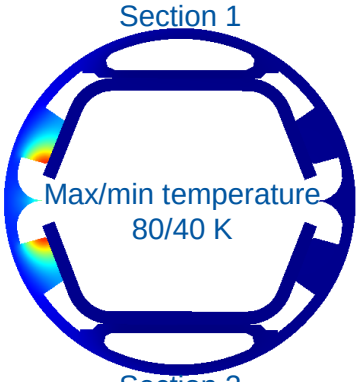
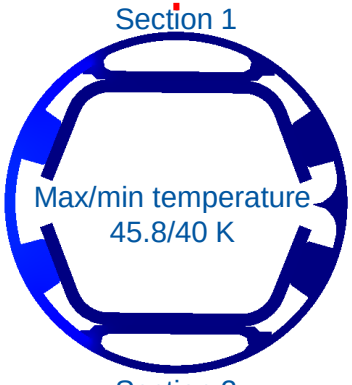
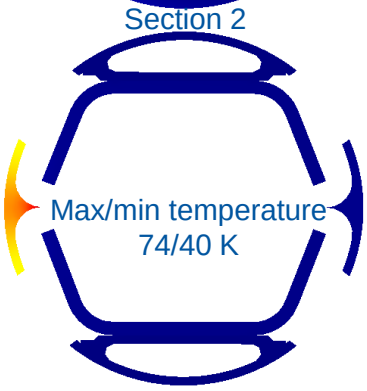


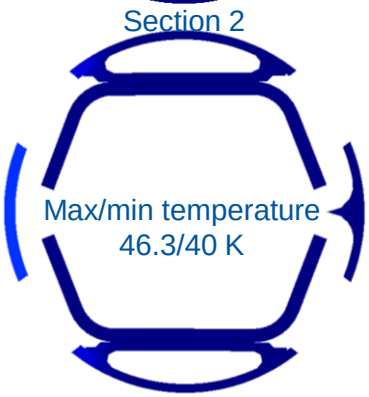


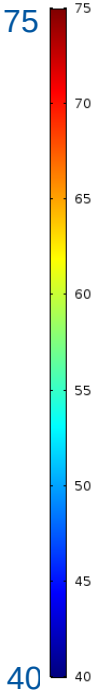
Most of the radiation is absorbed by the sawtooth.
Stiffeners don't act as a photon stoppers anymore.





High thermal conductivity in copper sawtooth layer helps to reduce temperatures

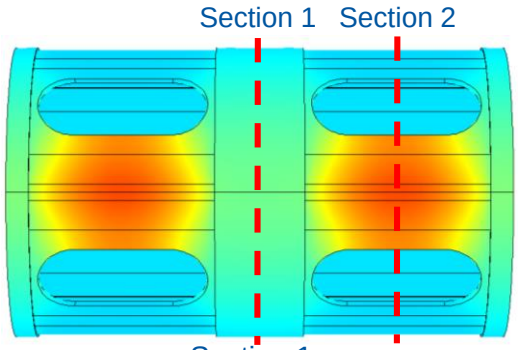


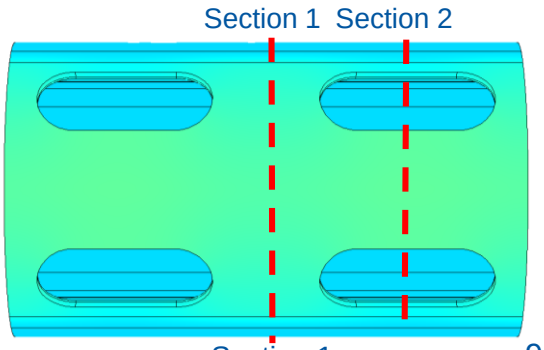


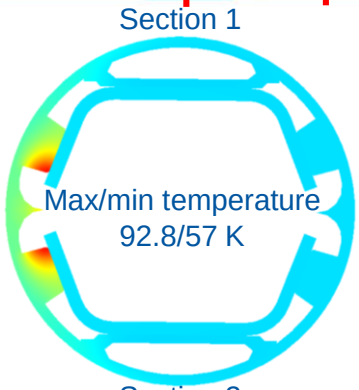
Thermal analysis

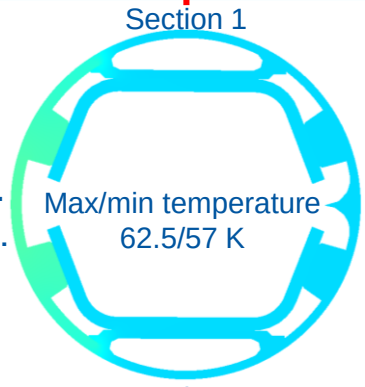
Temperature profile

Helium outlet conditions
57 K, 5000 W/m^{2}K, 50 bar









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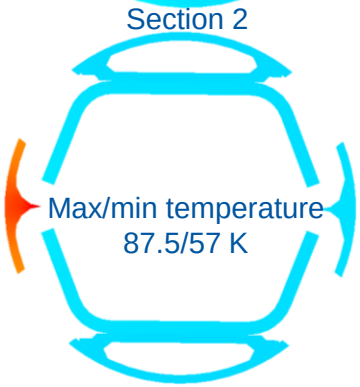
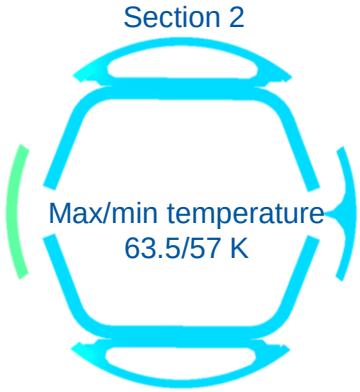
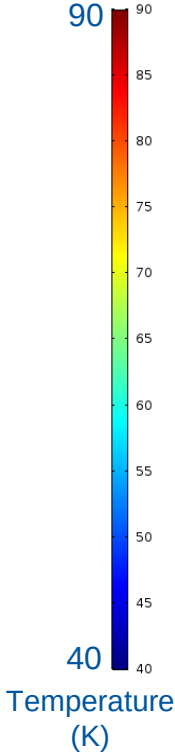
Stiffeners don't act as a photon stoppers anymore.





High thermal conductivity in copper sawtooth layer helps to reduce temperatures



Thermal analysis

End dipole absorber

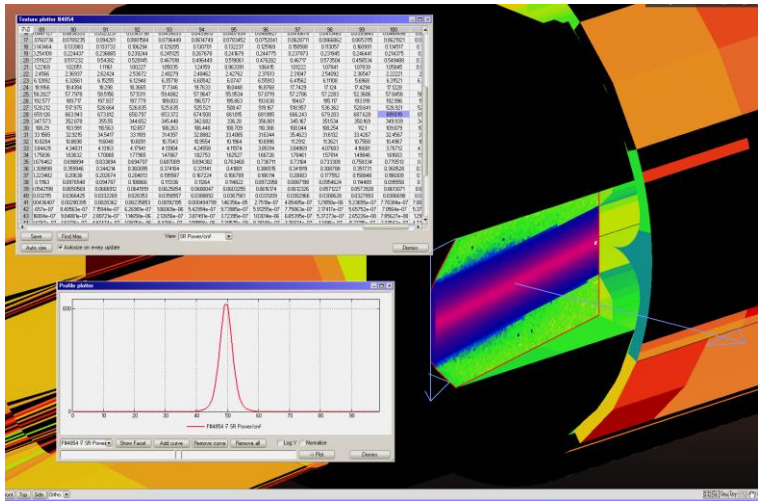
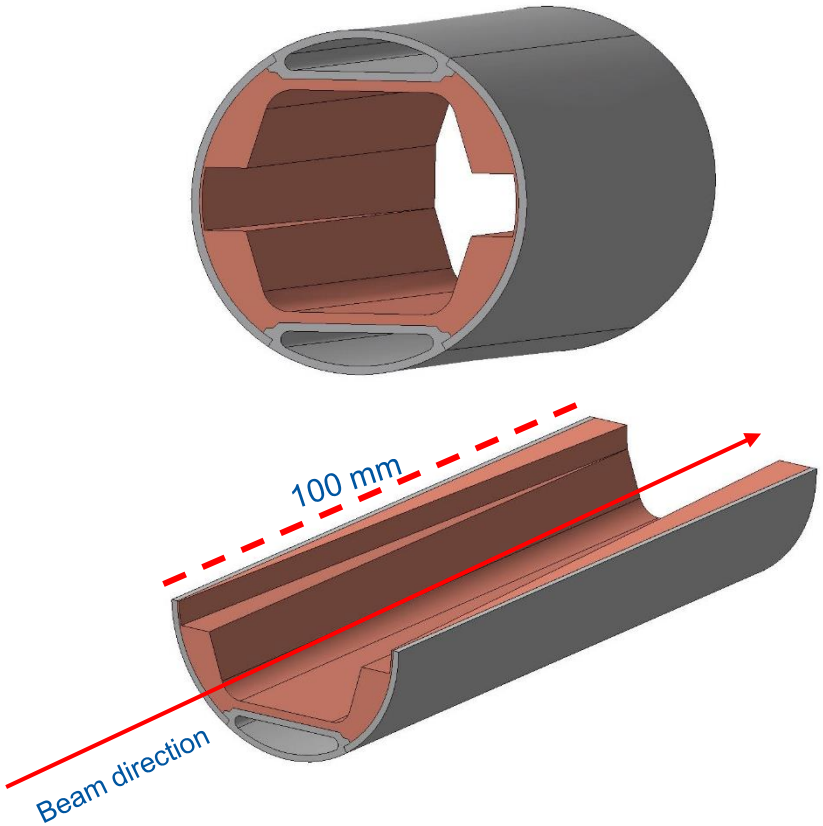


*image by Ignasi Bellafont

85 W (with sawtooth).
Points with more than **600 W/cm²**

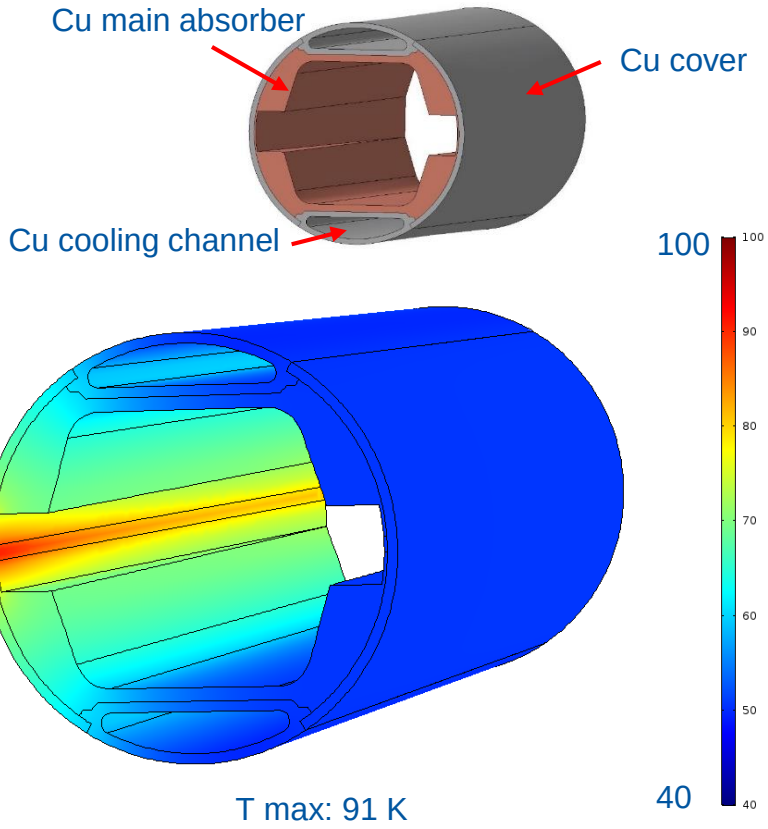
Due to the high SR density at the end of the dipole, an absorber has been designed in order to reduce as much as possible power density in this area.

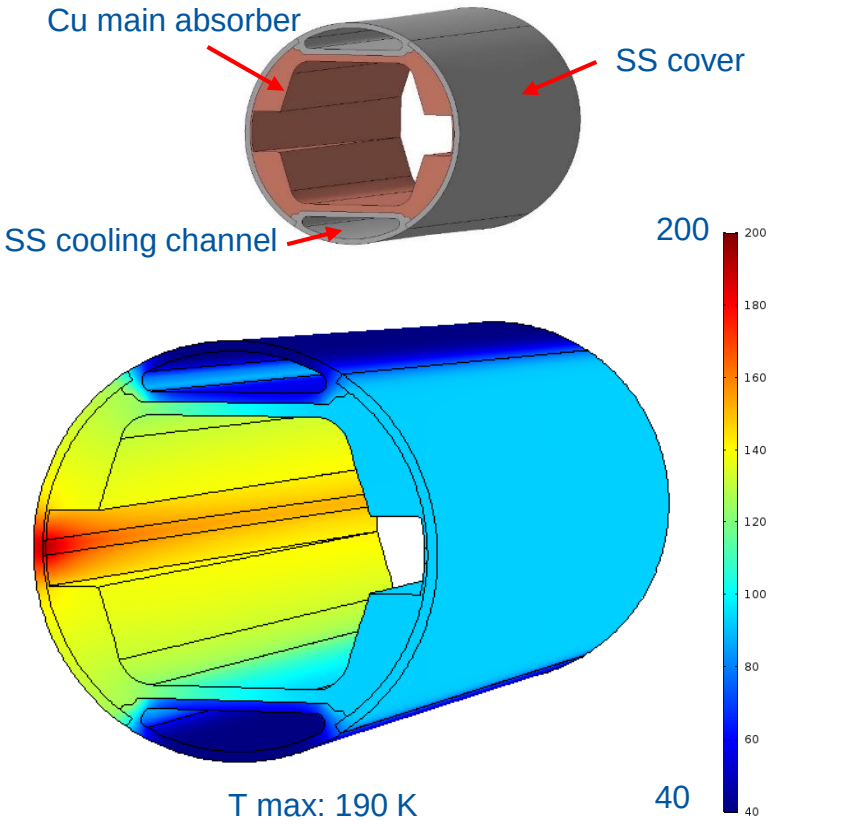
Preliminary end absorber design



Thermal analysis

End dipole absorber

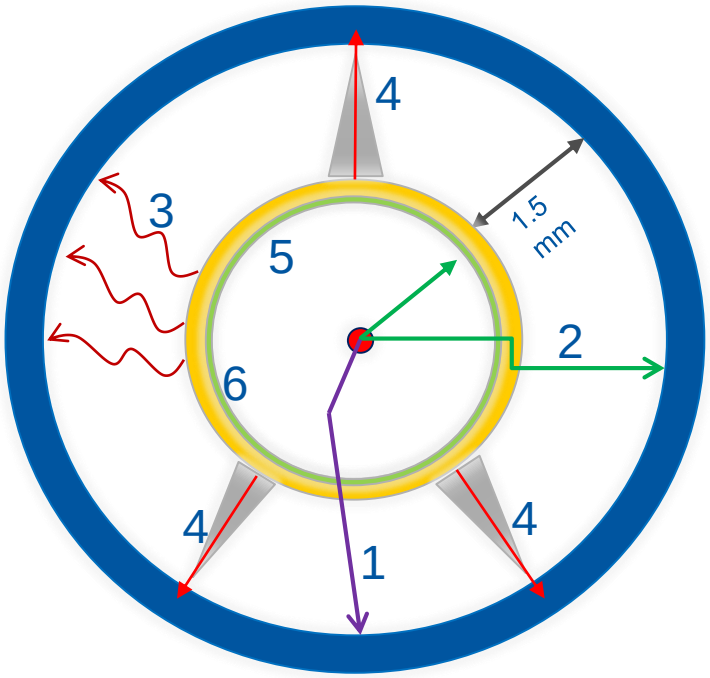




Temperatures in the absorber reach very high values due to the SR stopped at the end of the dipole.
Further studies including different designs, with different cooling scheme, will be carried out.

Thermal analysis

Heat transferred to cold bore



			Reflector	Sawtooth
1	•	Nuclear scattering:	191 mW/m	191 mW/m
2	•	Synchrotron radiation:	2.4 mW/m	0.5 mW/m
3	•	Thermal radiation:	1 mW/m	0.6 mW/m
4	•	Beam screen supports:	100 mW/m	75 mW/m
5	•	~~Image currents~~		
6	•	~~Electron cloud effect~~		

Max power allowed: 300 mW/m

Total thermal load transferred to cold bore with sawtooth: 267.1 mW/m

Conclusions

Beam screen geometry

- New proposal changing the reflectors by a copper layer with sawtooth shape has been analysed.

Mechanical design

- Simulations during a magnet quench have been done taking into account the Joule effect and using 3D massive finite element model. High copper electrical conductivity produces higher Lorentz forces in the new co-laminated area. As a consequence of that, the outer beams screen is pushed away producing high stress area between pumping holes and a separation between stiffeners and primary chamber. Even plasticity is not reached in any of its points, max stress is close to the limit, so further studies in order to reduce beam screen stress should be done.

Thermal analysis

- Taking into account synchrotron radiation impact during nominal behaviour, temperatures remain on the range allowed. In general terms, temperature decreases due to: Firstly, SR absorption area is reduced thanks to the sawtooth. Secondly, high Cu thermal conductivity improves heat transferred from sawtooth area to cooling channels.

- Synchrotron radiation impact at end dipole absorber has been analyzed. High temperatures reached makes necessary to study in deep this area. Further studies of the end absorber and of the beam screen extremities in a more general way will be carried out.

- Main types of heat transfer from beam screen to cold bore has been studied. Heat load remains below the limit.

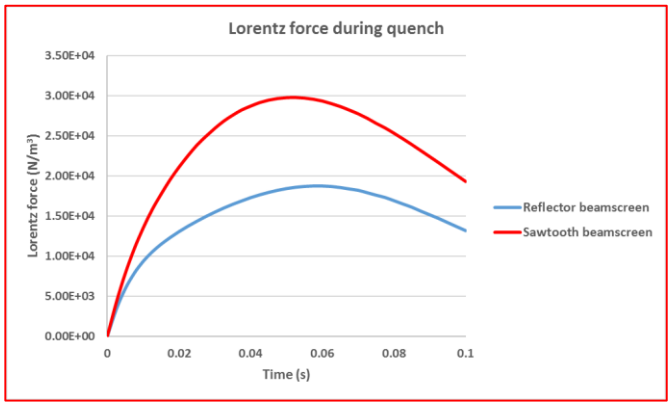
Next steps

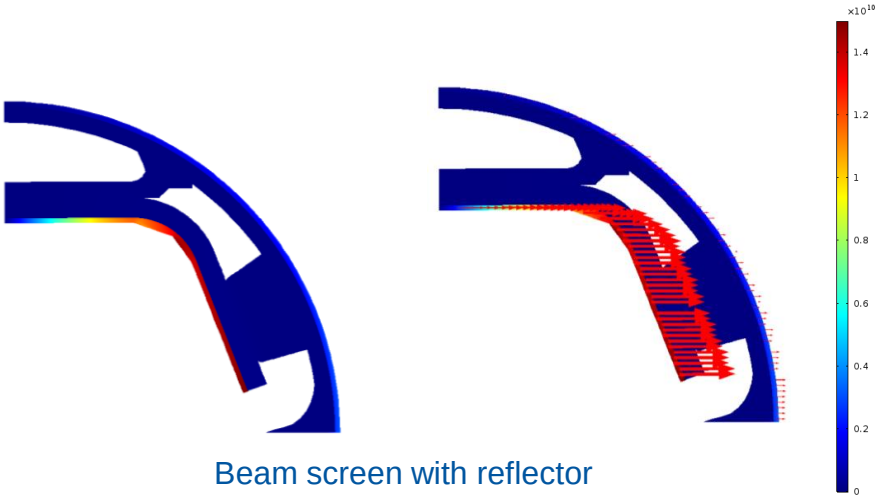
- Study the large scale manufacturing (more difficult with the sawtooth version).
- Check mechanical behaviour of beam screen on future geometry updates.
- Beam screen thermal analysis with future SynRad data.
- Detailed study of end dipole absorber as well as beam screen extremities.

THANK YOU FOR YOUR ATTENTION

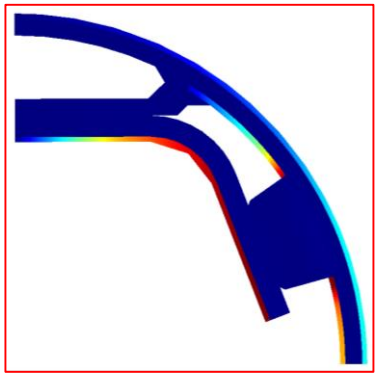
Mechanical Design

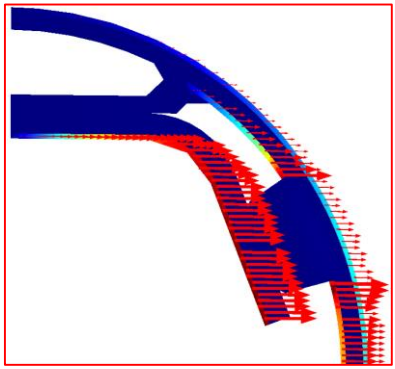
Lorentz forces





Beam screen with reflector





Beam screen with sawtooth

New copper part increases 65% Lorentz force.
High copper electrical conductivity produces more induces currents, thus, more Lorentz force during quench.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