BOOSTER MAGNETS

FCCIS 2023 WP2 workshop

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Outline

Impact on the magnets of the larger vacuum chamber

Studies on detailed design of dipole:

- Hysteresis effects at low field
- Eddy current effects at higher ramp rates
- Stray fields at injection energy

Conclusion

Future work

Impact of the larger Ø60 mm vacuum chamber

Dipole and quadrupole limited impact on technical feasibility.

Larger radius (31.5 mm to 32.5 mm)[1] → More ampere turns and larger magnet → c. 5% increase to CAPEX + lifetime OPEX. Maybe lower with detailed re-optimisation

Technically feasible sextupole tip field should remain bellow 0.8 T, with 0.7 T being more common. Therefore B'' = 2S < 1500 Tm^{-2}

1 Vacuum inner radius has increased from 25 mm to 30 mm, however 4 mm bake-out jacket is removed.

Developments on the dipole

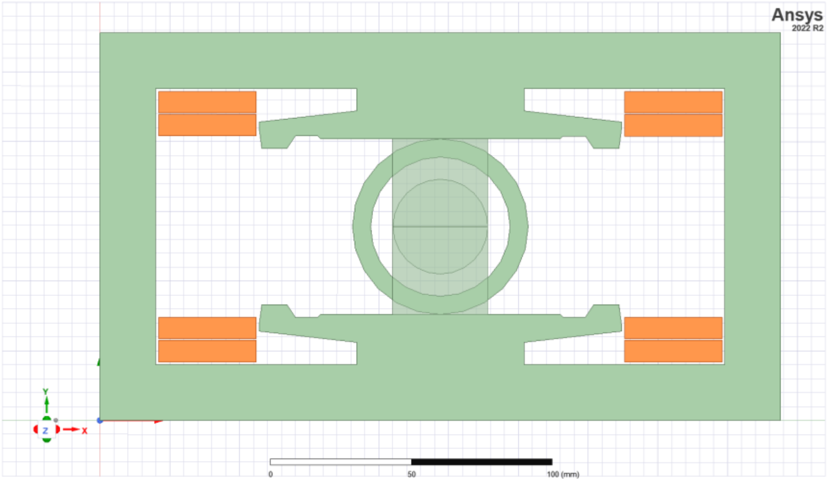
Changes to baseline:

- Updated from O to H topology to move the coil out of the mid-plane → increased radiation hardness
- Increased aperture for 60 mm vacuum chamber

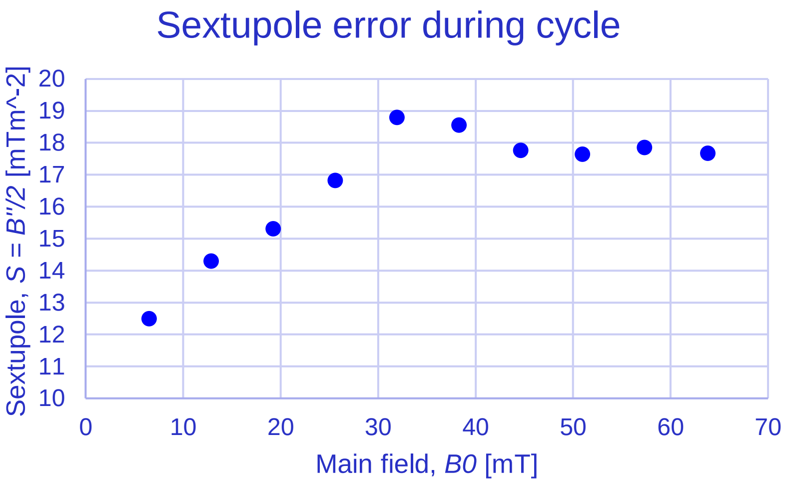
Preliminary study with numerical simulation of impacts on field quality at injection energy of:

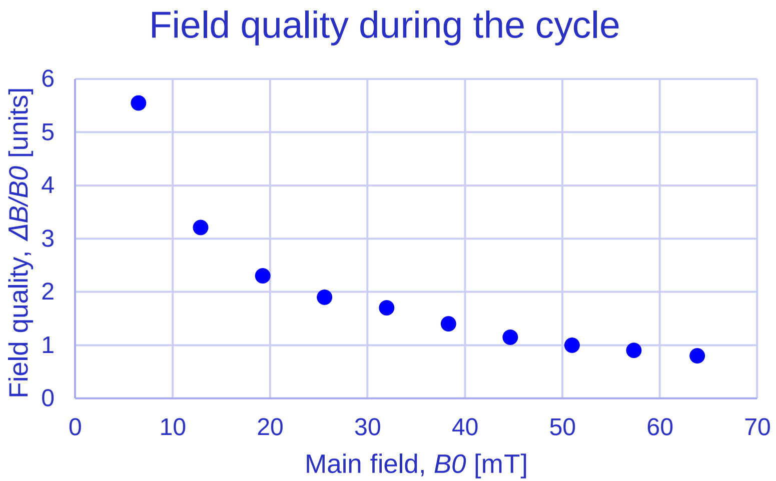
- Hysteretic effects in the yoke
- Earth magnetic field
- Eddy currents induced in the vacuum chamber

Consideration of a C topology motivated by automisation of magnetic measurement and completeness



Hysteresis in H shape dipole





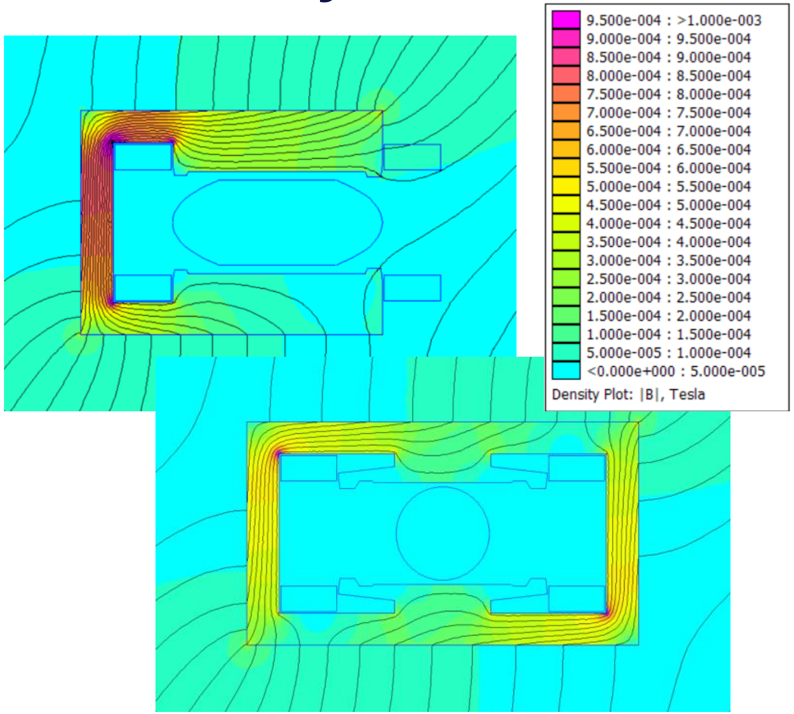
Good field region ±17 mm

Earth magnetic field and other stray field

	H shape	C shape
Shielding factor x	> 400	> 10
Shielding factor y	> 65	> 30
Δ Normal FQ	<0.(1) units	<0.(1) units
Δ Skew FQ	<0.(1) units	3 units
ΔB0	0.(8) units	1.(3) units

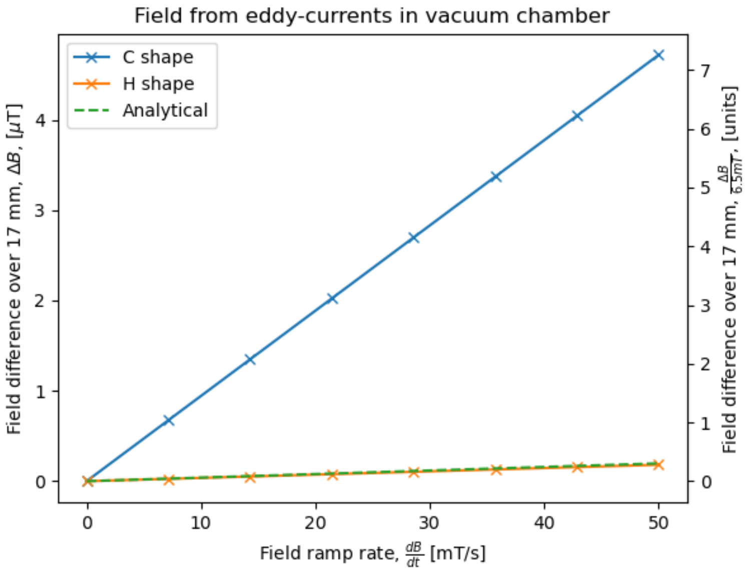
The C shape dipole is poor at shielding background field, in particular in the x-plane

The system is sufficiently linear to make predictions based upon shielding factor to 1 sig fig.

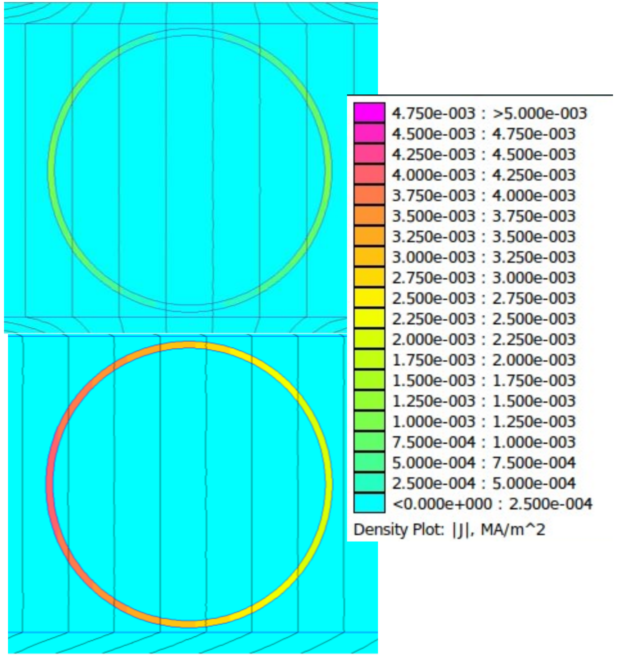


H and C shape dipole w/o excitation shielding the earth’s magnetic field [-22.3, 42.3] µT

Vacuum tube eddy field



Eq.12 of Y. Chen et.al, 2019, *An expression for the eddy field in a circular vacuum chamber for HEPS booster dipole,* https://arxiv.org/pdf/1910.09781.pdf



Eddy currents in the vacuum chamber for 25.4 mT/s Ramp H shape dipole (above) and C shape (bellow)

Quick comment on yoke eddy field

Detailed numerical simulation has not yet been performed

Not expected to be a feasibility issue

- Most pessimistic operating frequency is 1.5 Hz, in the Z case. Skin depth of electrical steel @ 1.5 Hz is 8.7 mm
- Industrial standards for electrical steel are between 1 mm and 0.35 mm.

Will still be checked. Lamination thickness is a cost driver, both for stamping stroke rate and stacking.

Conclusions

The larger vacuum chamber is technically feasible with a slight cost increase and a reduced sextupole field.

The dipole baseline is updated to H. Consideration of hysteresis, vacuum eddy field and impact of stray field has further confirmed the feasibility of 10 units.

Ramp rates > 25.4 mT/s are likely to be feasible for the magnet system.

A C shape dipole has been considered but is unlikely to be able to meet 10 units.

WIP and the future

Techniques developed are being expanded to the other magnets and used in the detailed optimisaiton.

A first order sizing model of the magnetic elements is being developed to integrate into the global cost optimsation model being developed by SY-EPC.

- Possibility to feedback into magnet reqs?

The design of the >20 mTm corrector magnets is ongoing.

Thank you for you attention