COMSOL simulation of nTMM setup
2026-07-29

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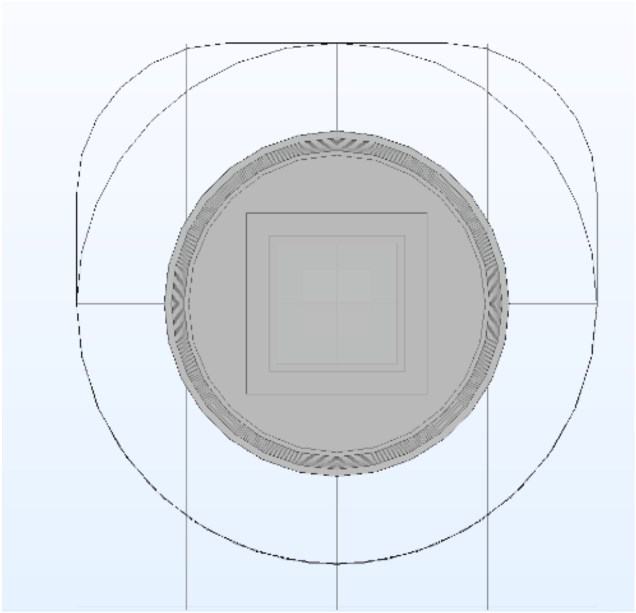
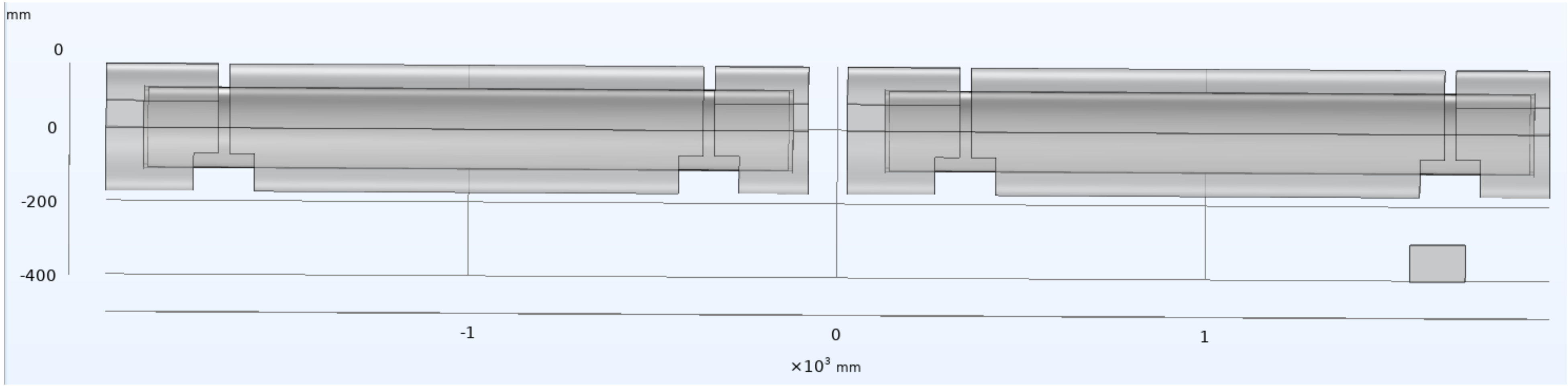
New geometry

- Revised model where dimensions are checked against the CAD model.
- 8 individual layers of wires are modelled as homogenised multi turn coils.
- End caps are different for each box.
- Magnetic shielding has different μ for inner (24050, 0.6 mm) and outer layer (11220, 0.3 mm).





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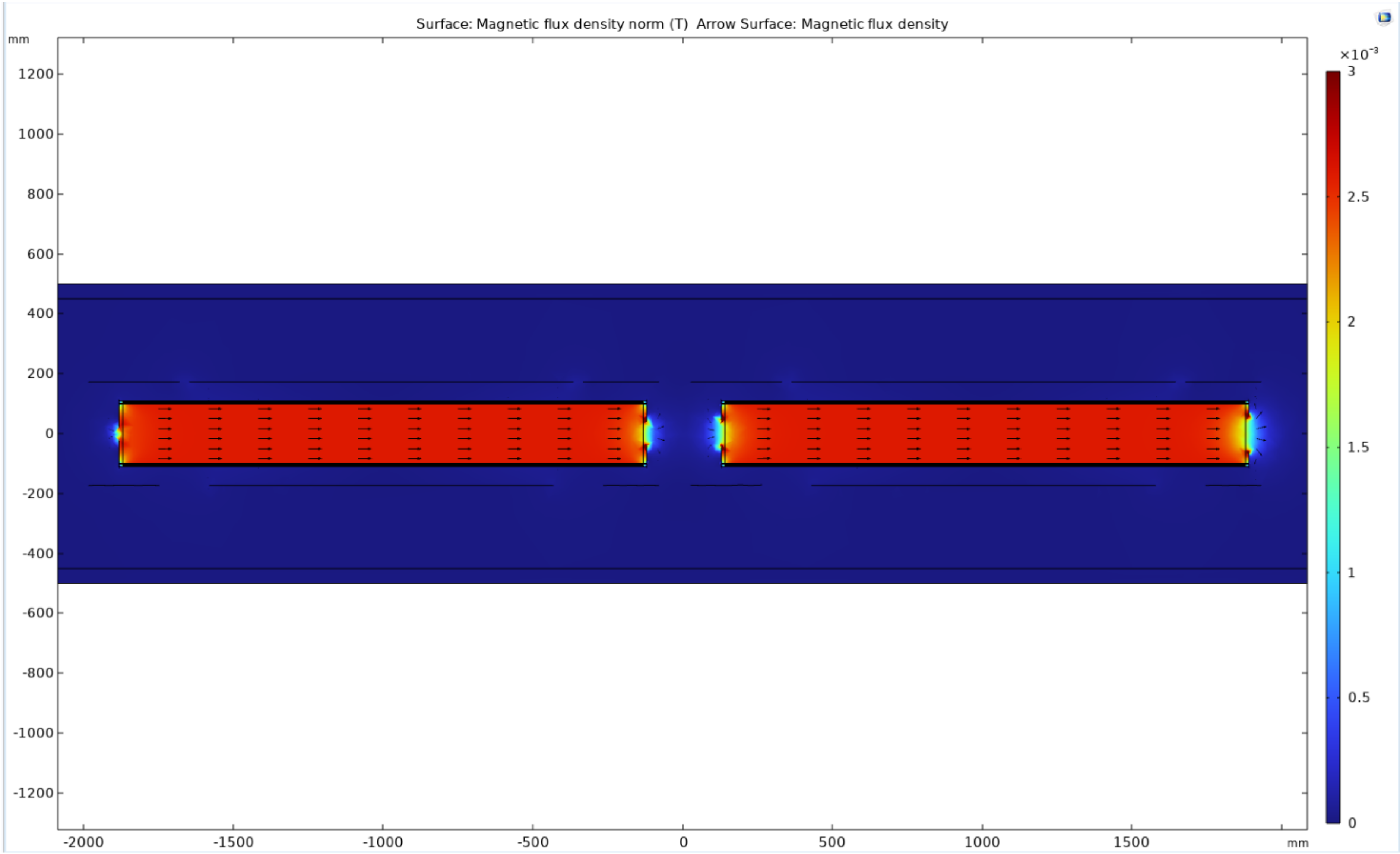
Simulation of coil field



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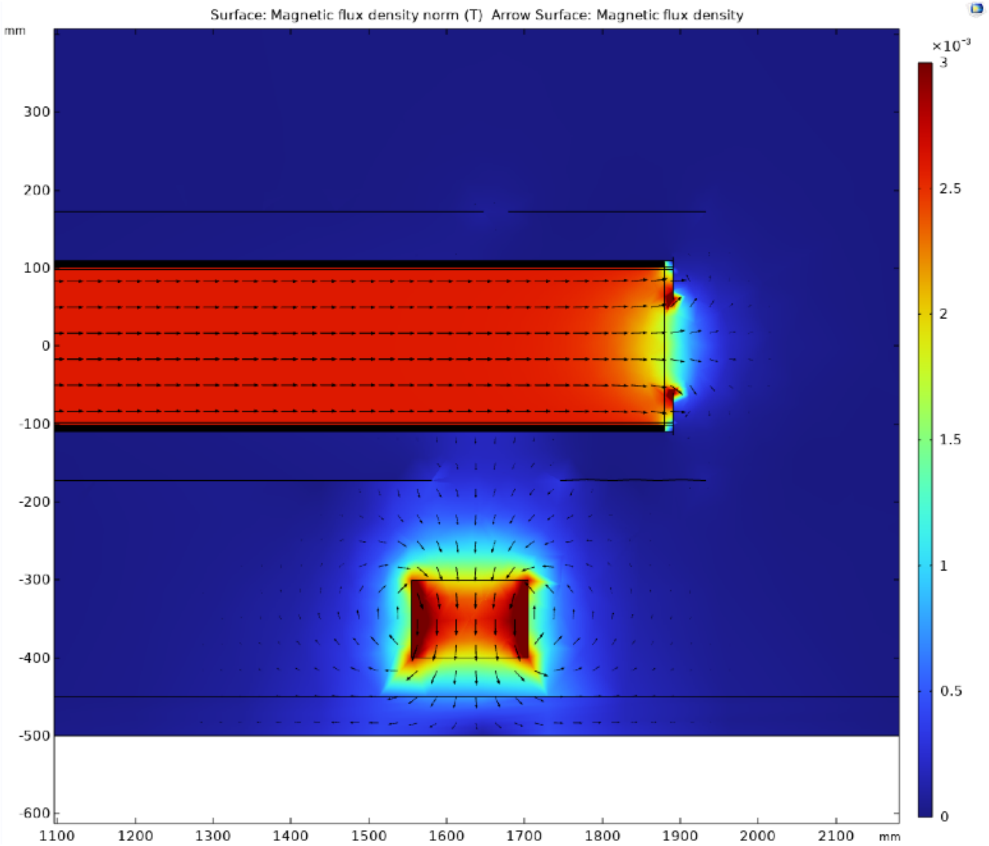
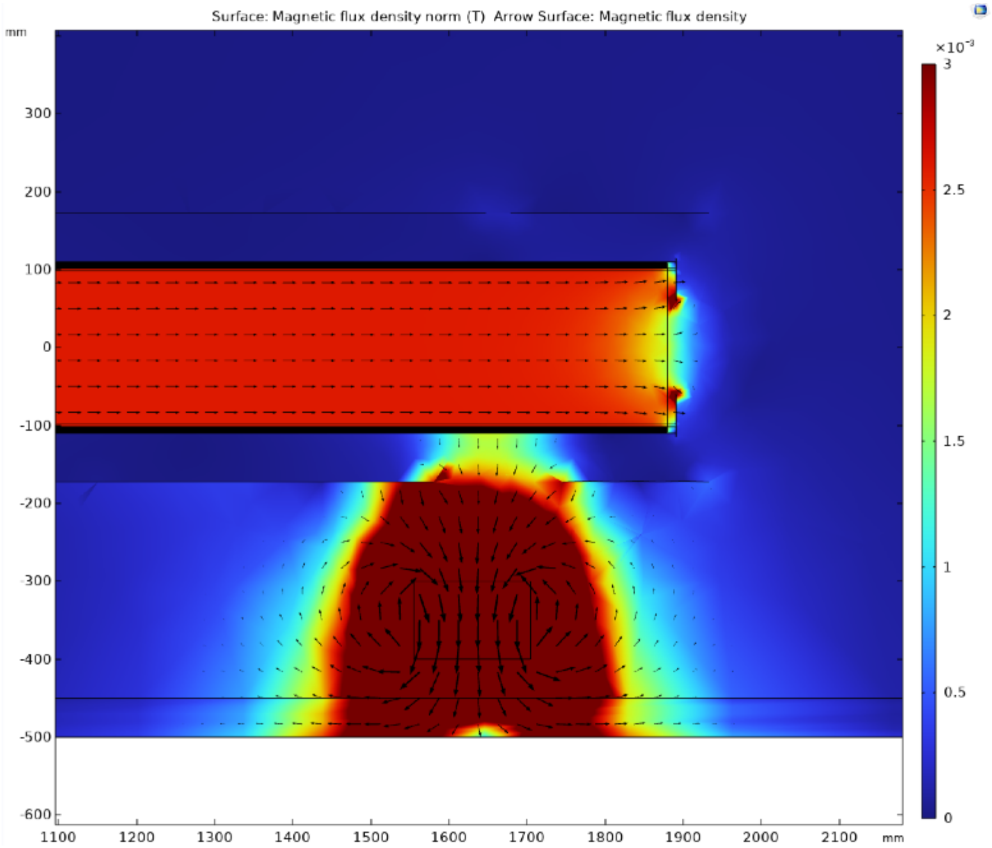
Simulation of coil field + a perturbation

Steel block with remanence magnetisation 50 G roughly at location of support



Steel block with remanence magnetisation 500 G roughly at location of support



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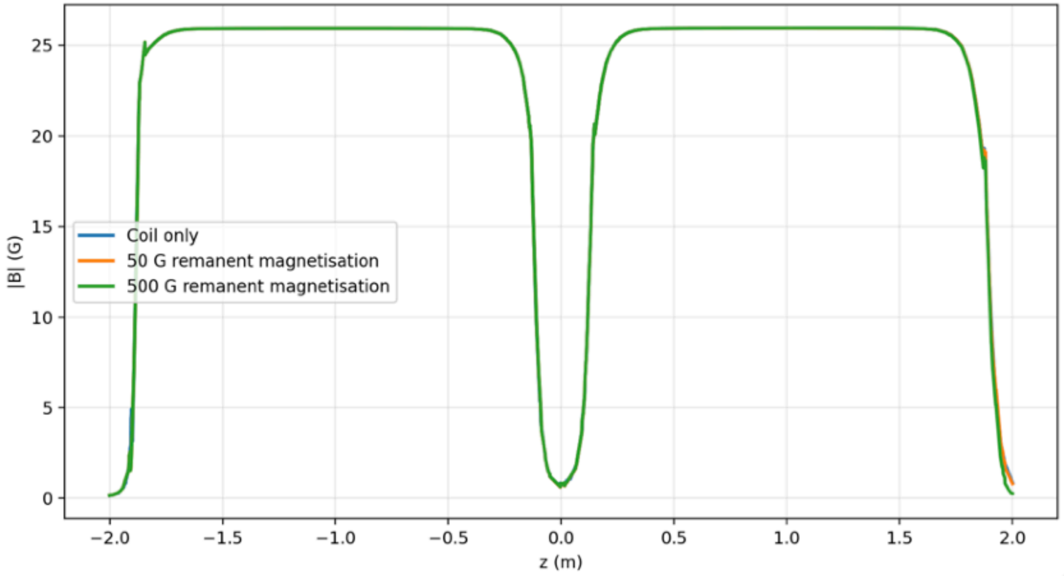
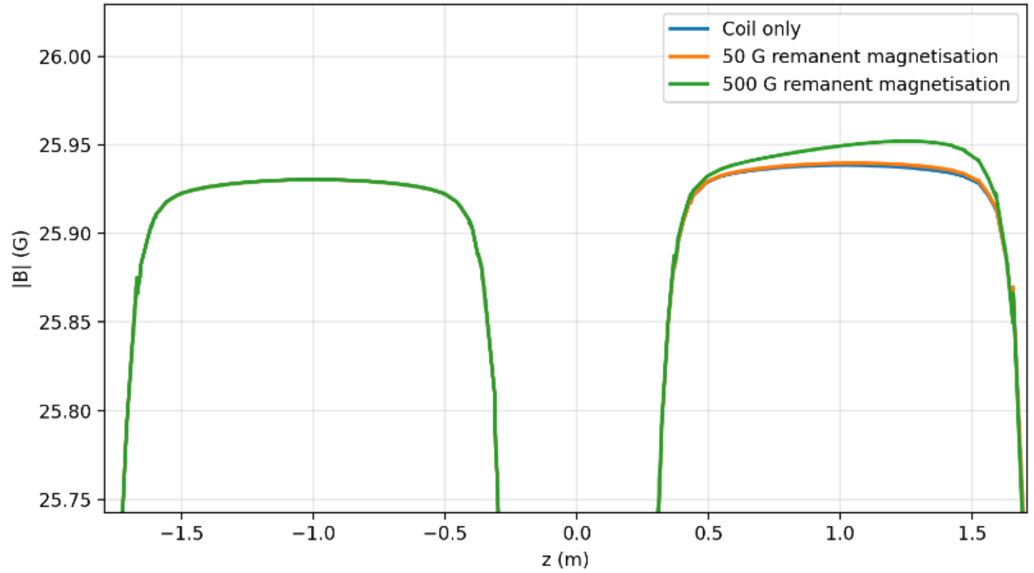
Simulation of coil field + a perturbation

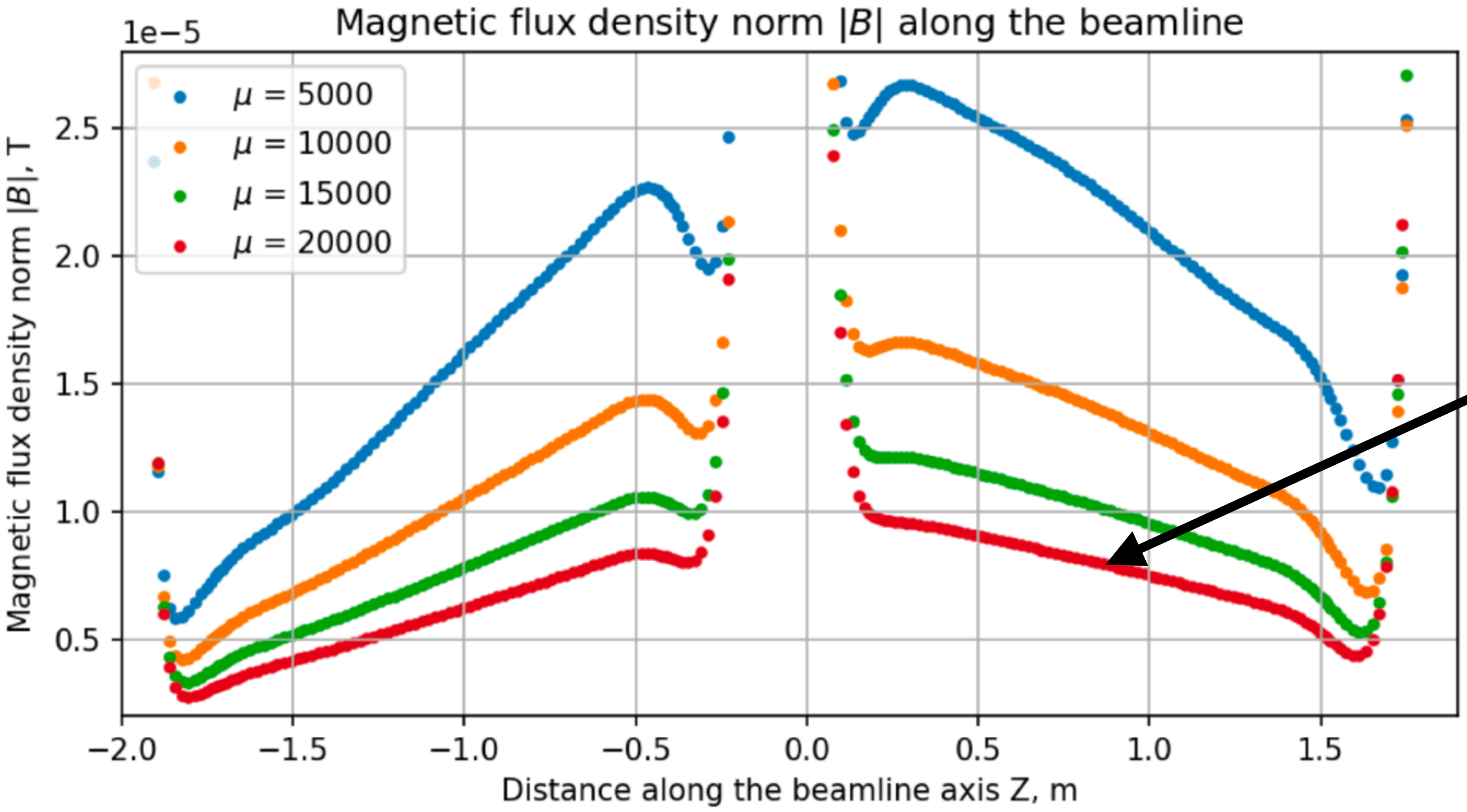
- There is a small difference between the magnetic fields in the two magnets (~ 0.01 G) even without any perturbation, probably due to end gap.
- Even the 500 G perturbation only adds about a 0.01 G difference inside the magnets.





Simulate with a scalar potential background

- This seems contradictory to German's result…



Variation over magnet by about 5 μT ≈ 0.05 G

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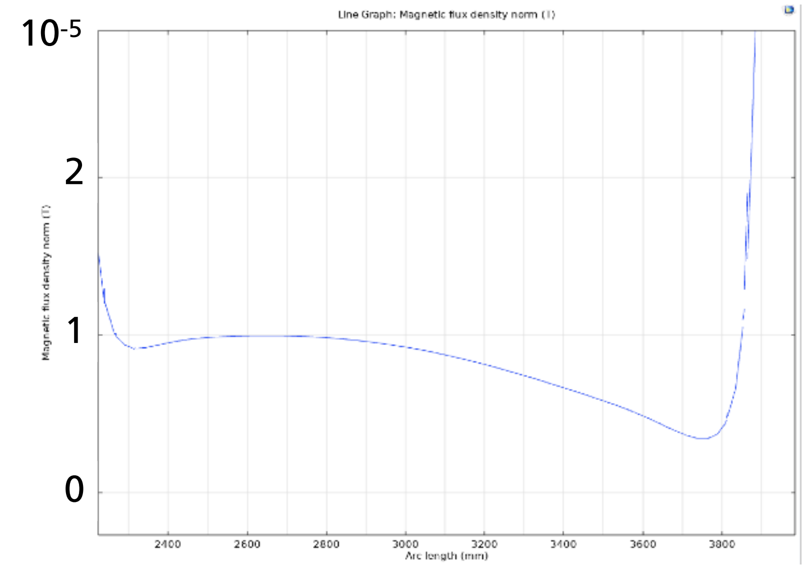
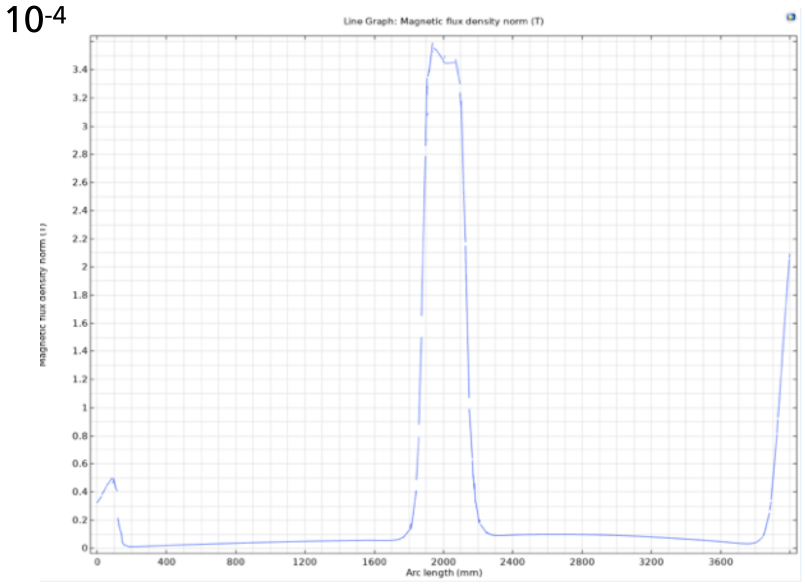
Magnetic scalar potential simulation

- I used a low-order approximation ($L \leq 6$) spherical harmonic fit from German and applied on the new model.
- Infinite element domain with scalar potential boundary condition.
- Exact coordinates to be verified, so may be off be a few centimetres.
- This is very similar to German's results.
- What I hadn't realised before is that the field between the magnets is huge (~350 μT)

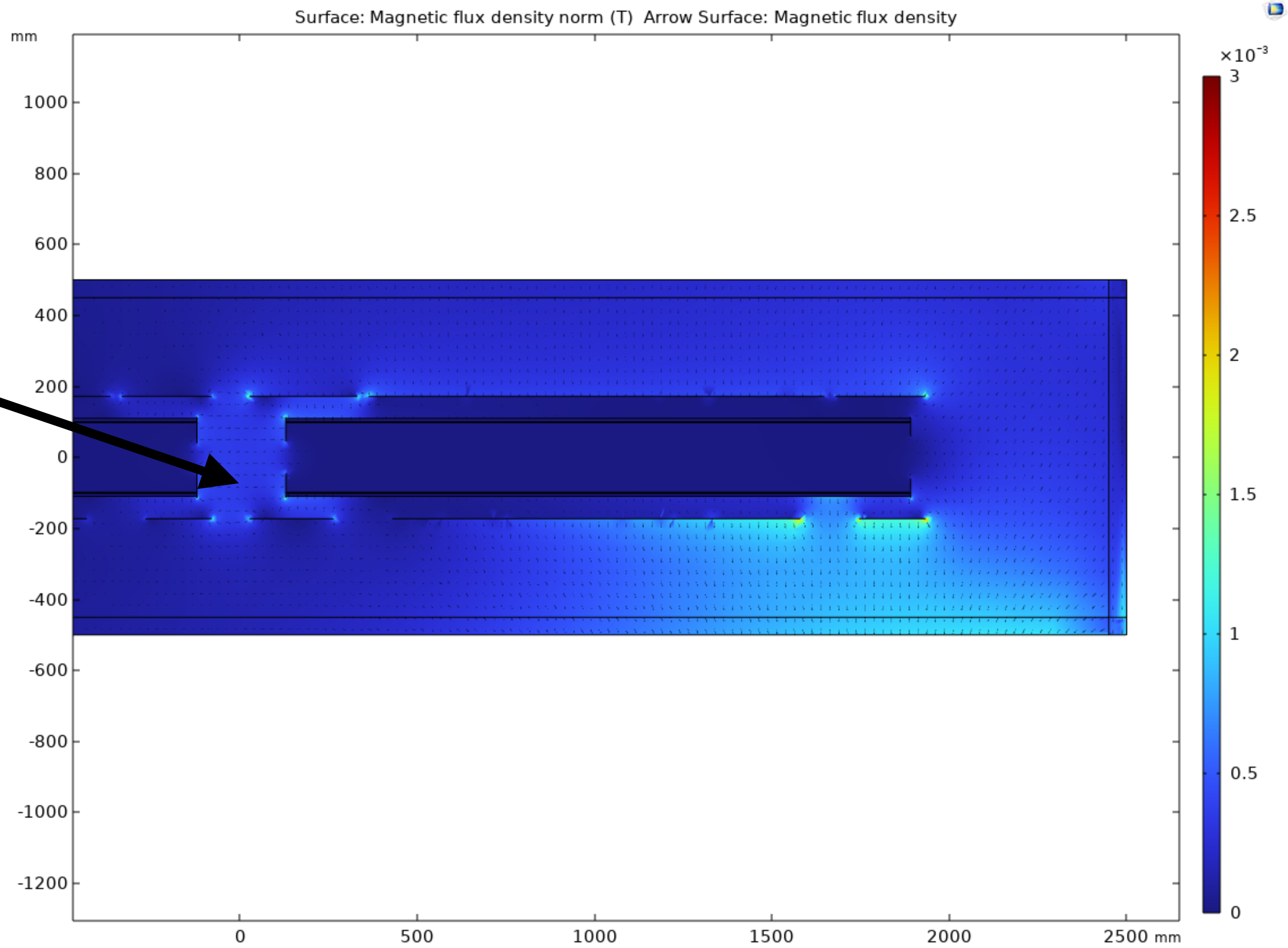




Simulation with magnetic scalar potential

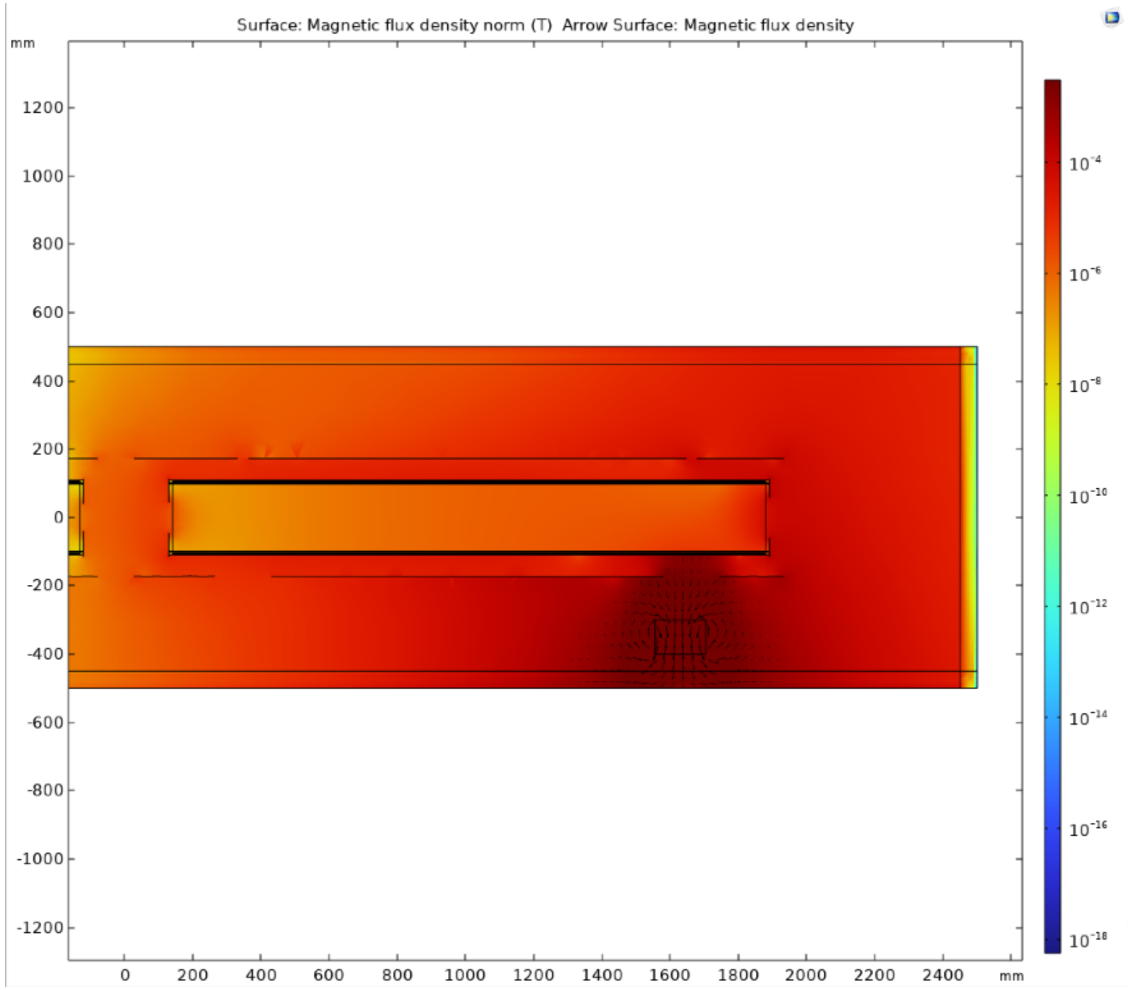
The field between the inner shields is stronger than the field outside?

This is a much more significant source of field in the magnets than the gap below the shield.



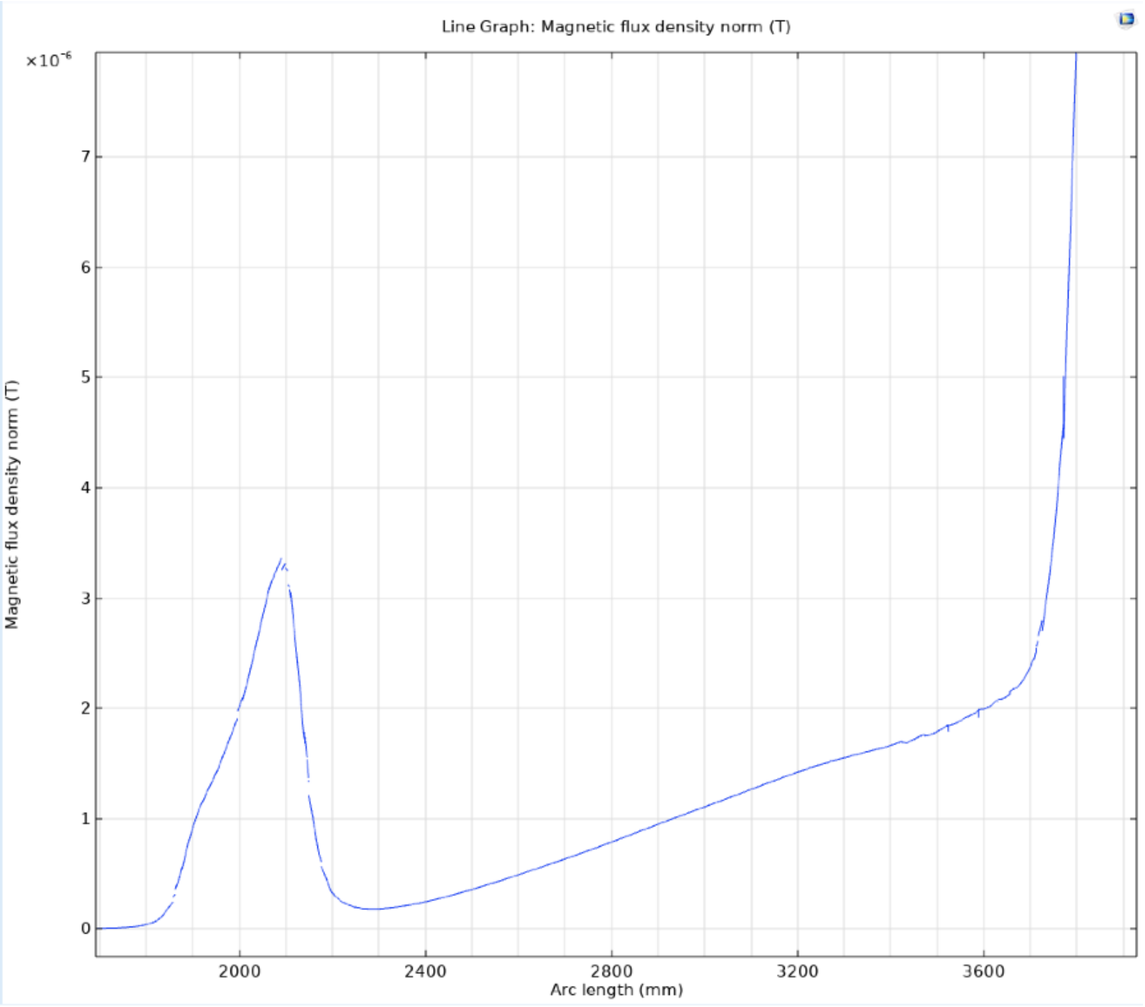
Simulation with perturbation block without coils

- Want to check if this is real or just an artefact of the scalar potential boundary fitting
- I simulated the block perturbation again but without the coils to see the distribution.
- Field plotted on logarithmic scale.



Simulation with perturbation block without coils

- There is a central peak but it is much weaker (~ 3 μT), such that the inner shield with end caps makes it negligible.
- To get a similar field magnitude in the central region, would need the block to have a remnant magnetisation of 5.8 T which seems unreasonable.
- On the other hand, the shield sits in a background field all around it, not only localised from a block.



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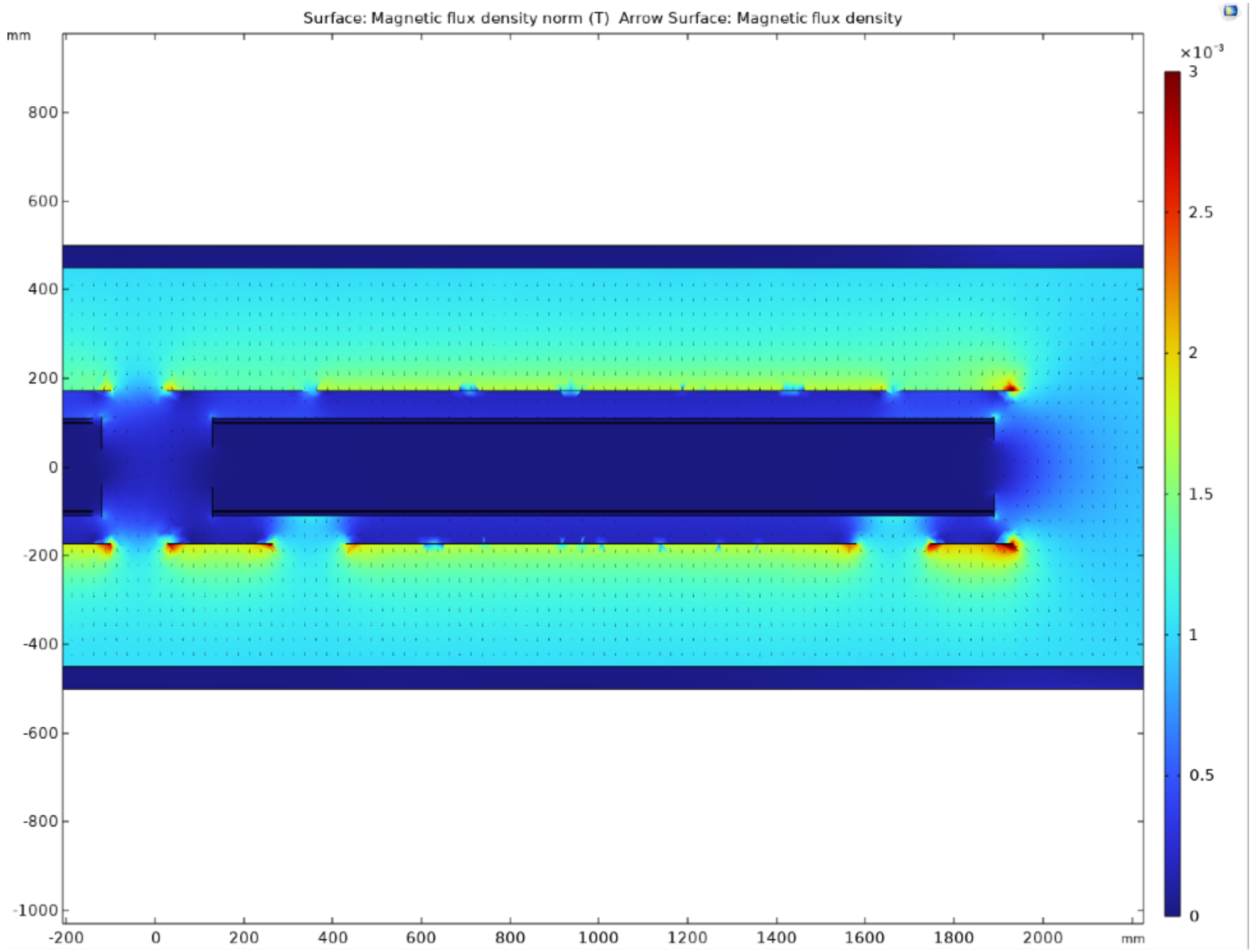
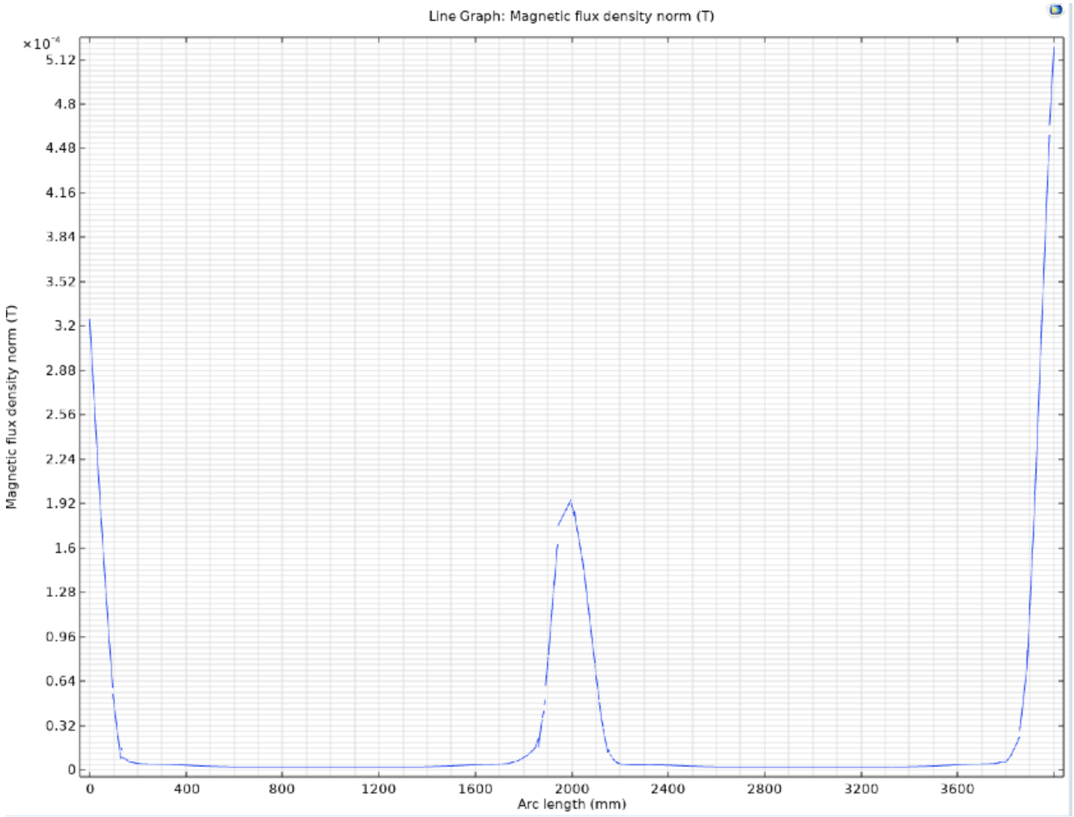
Simulation with constant background field

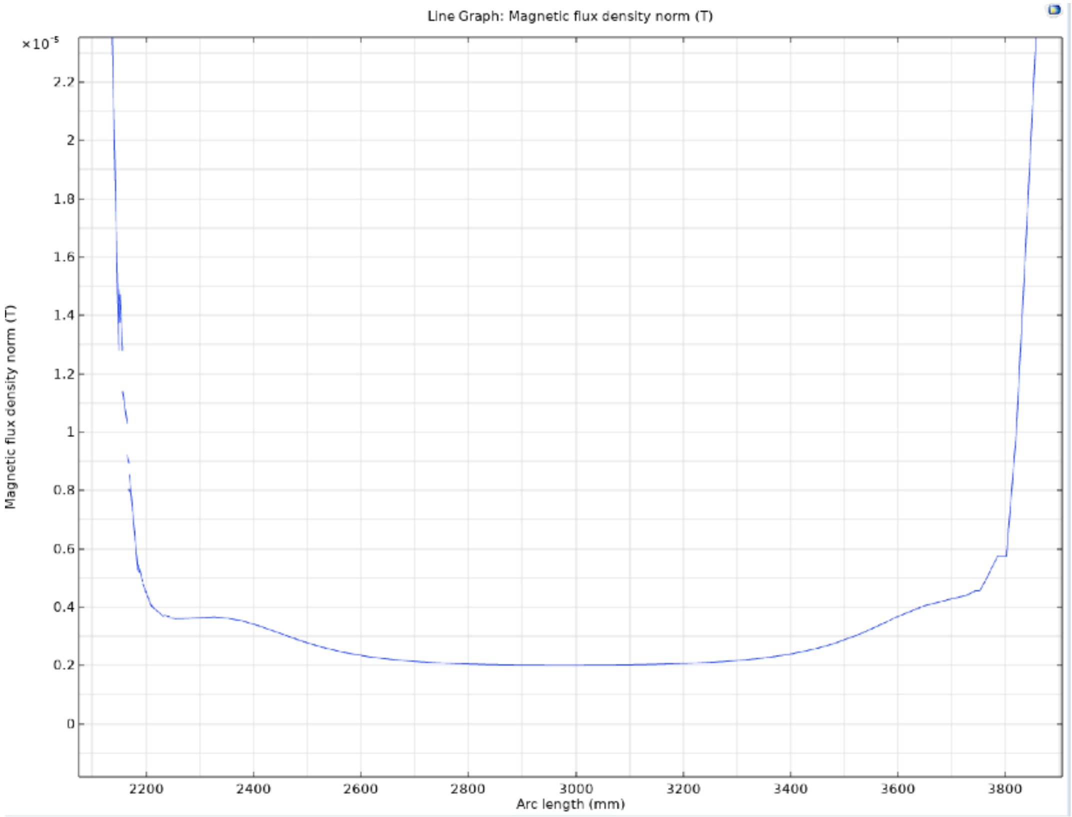
- To check this, I simulate the mu-metal response to a constant background field of 1 mT, first perpendicular to the shield.



Simulation with vertical background field

- This shows a peak at about 190 µT between the magnets but relatively stable field inside (within about 2 µT/0.02 G), as expected.





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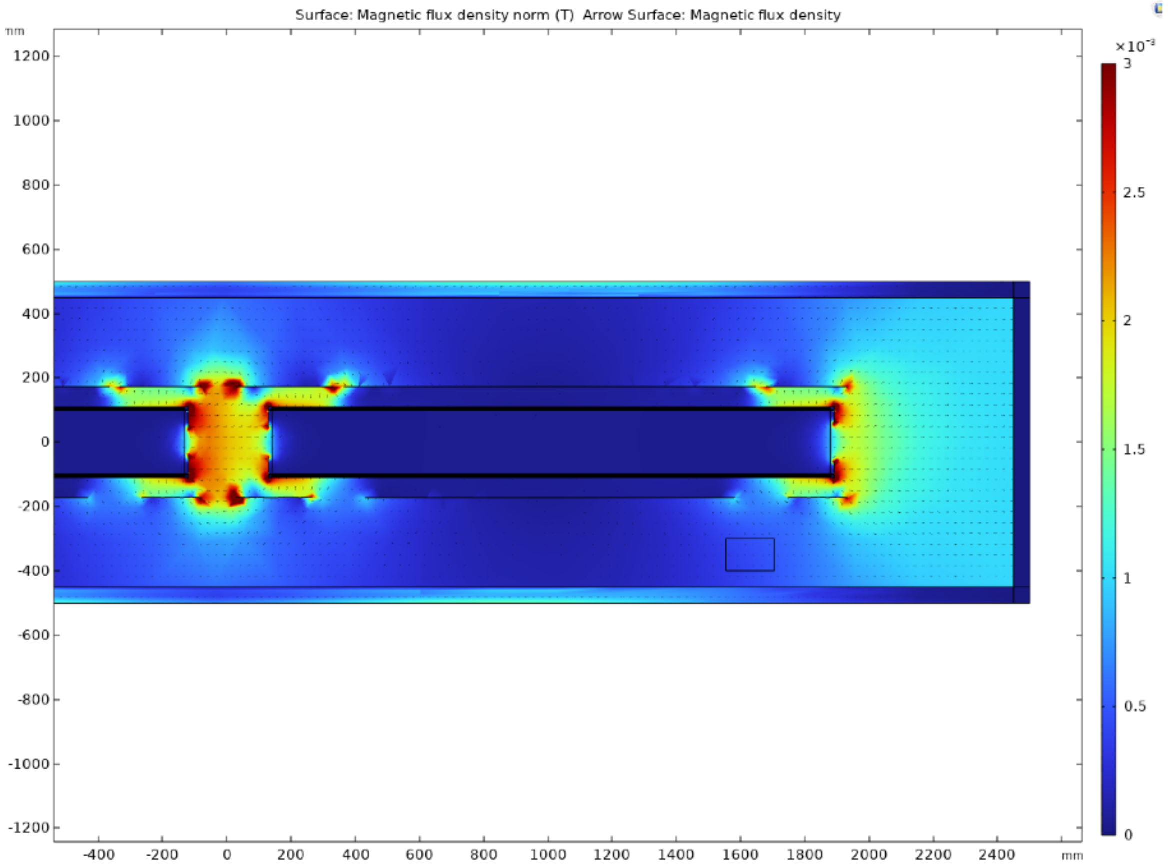
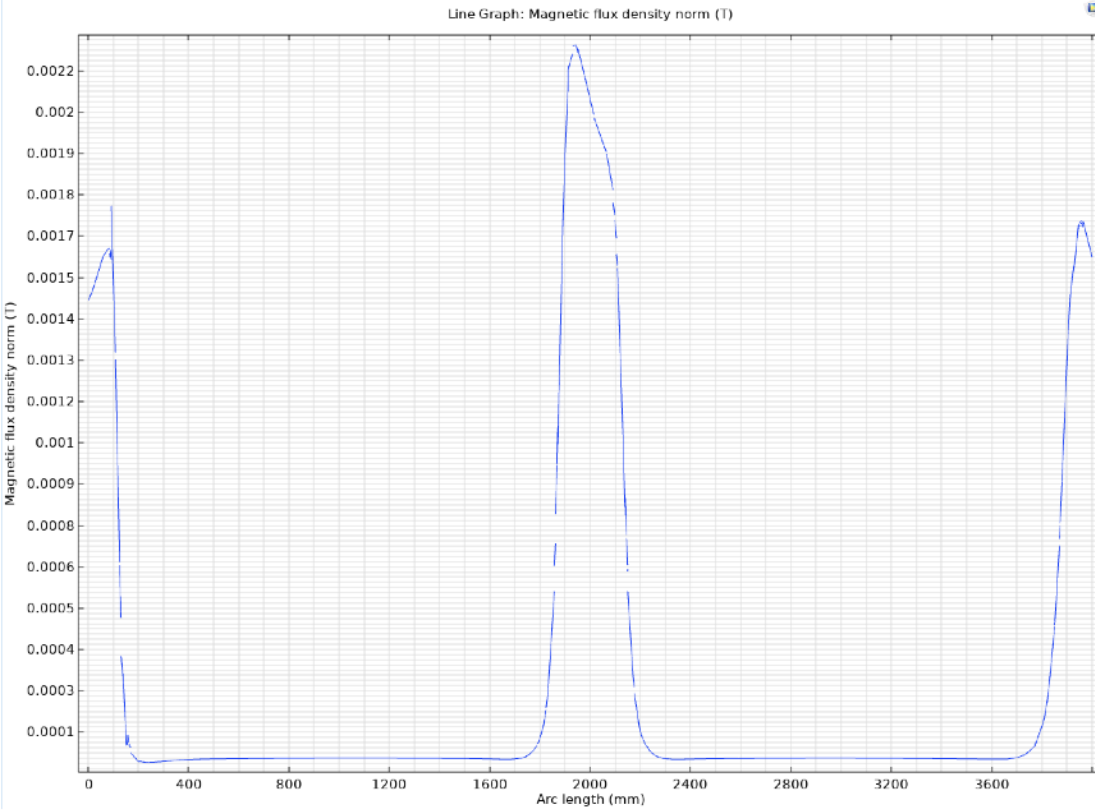
Simulation with horizontal background field

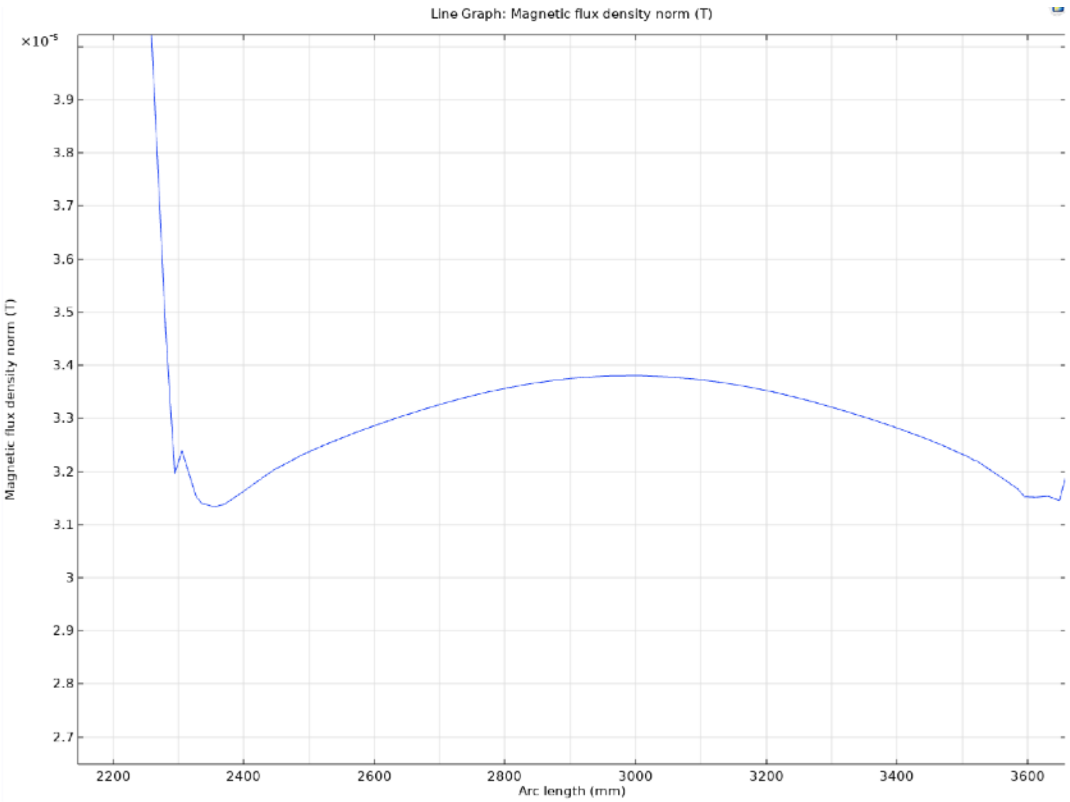
- This is the ”smoking gun”, showing a large amplification in field strength where field lines jumps from the outer mumetal layer in one magnet to the other.



Simulation with horizontal background field

- Now the peak field reaches 2.2 mT, above the background levels.
- Still, variation in the magnets are not huge in this case (~ 2 μT). However, the real background field is not constant, so maybe that's the cause.





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Conclusions so far

- It cannot be excluded that German's simulations are correct, in which case the field homogeneity for nTMM-1 is on the same order as the scanning step of 0.04 G. Doesn't invalidate experiment, but might impact sensitivity.
- If the field is primarily caused by leakage from the region between the magnets, then adding more mu-metal on the outer layer might not change much.
- Longitudinal component seems most dangerous.
- However, much remains to be understood…

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