Photon Conversion Target Wheel Eddy Current Simulations - Update

Ian Bailey and Ayash Alrashdi
Lancaster University / Cockcroft Institute

The Cockcroft Institute
of Accelerator Science and Technology

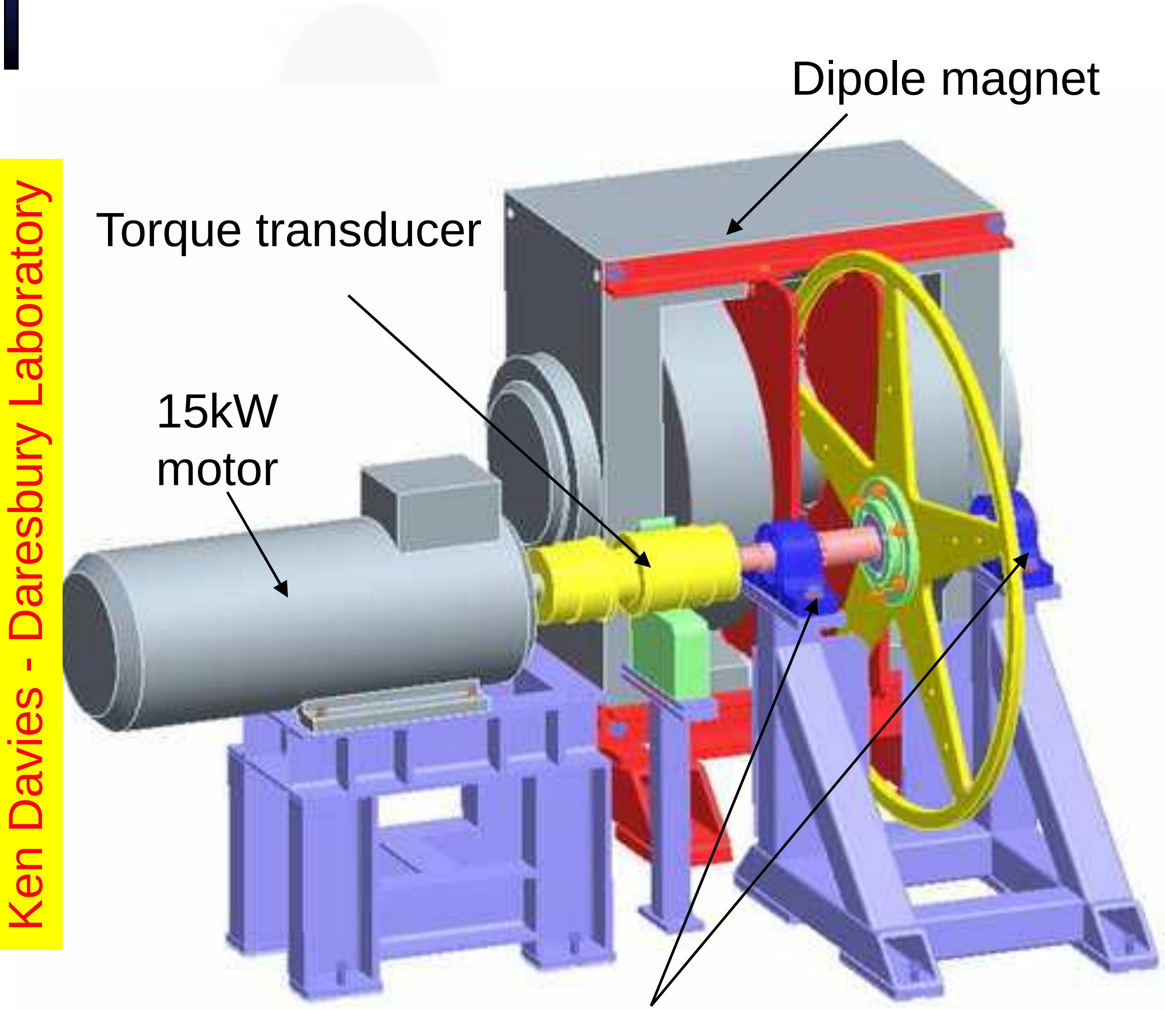
Outline

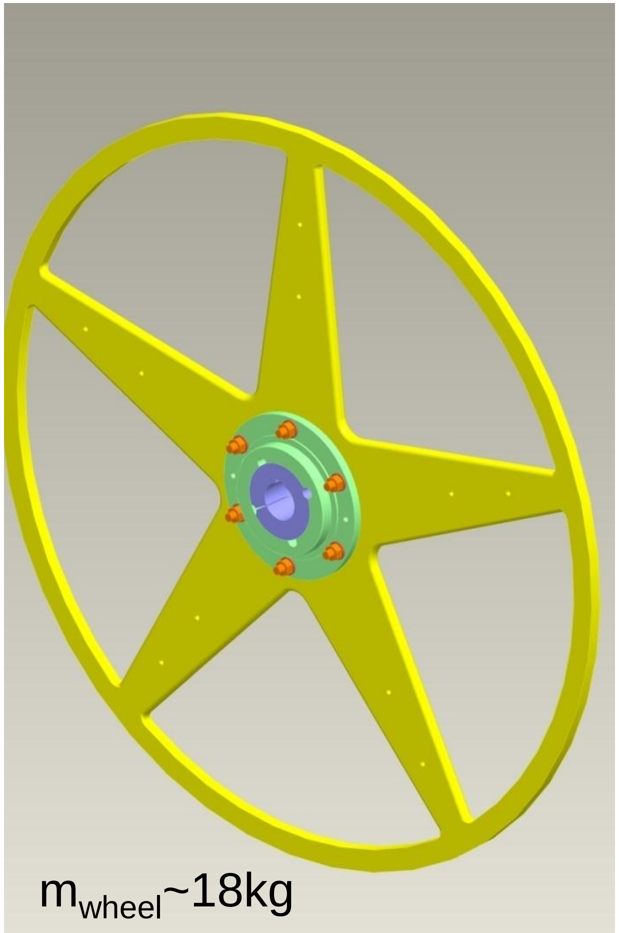
- ILC baseline target design
- Summary of previous eddy current simulations
- Fully-immersed target eddy current simulations

Target Prototype Design

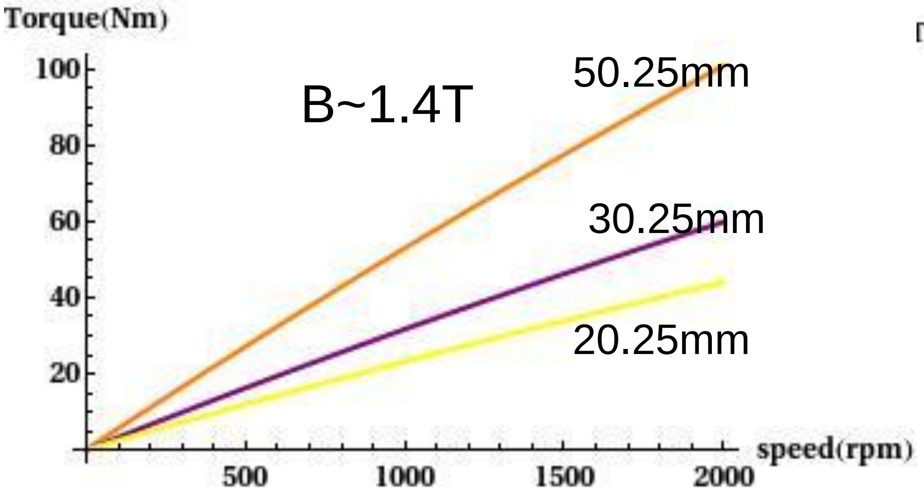
Prototype I - eddy current and mechanical stability

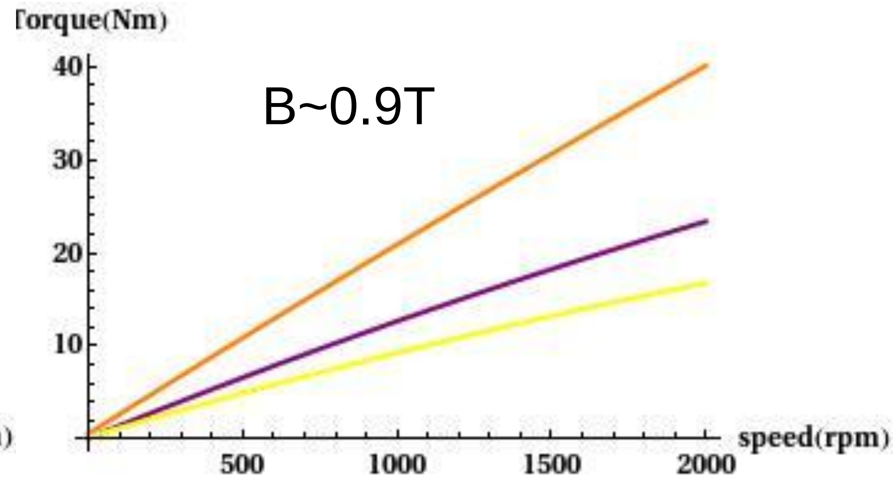
Ken Davies - Daresbury Laboratory

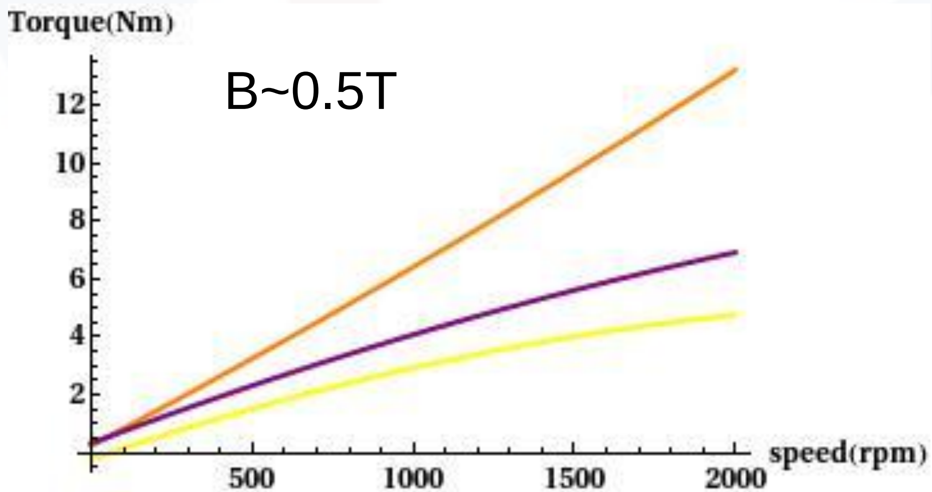




Effect of B Field on Average Torque





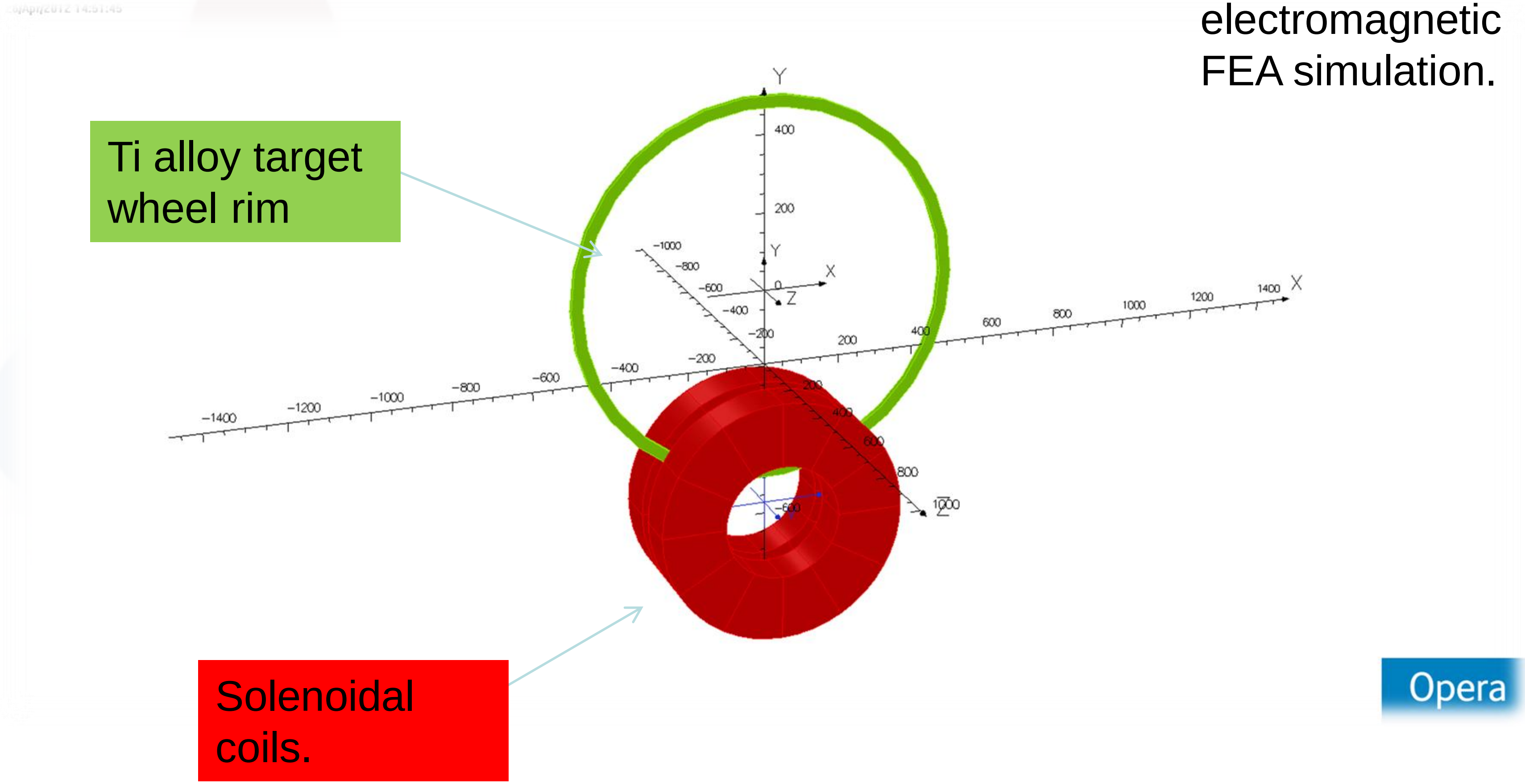


The plots show a quadratic fit to the measured torques (≤ 1500rpm) where the effects due to bearing friction have been removed.

The colours represent different immersion depths of the wheel in the field.

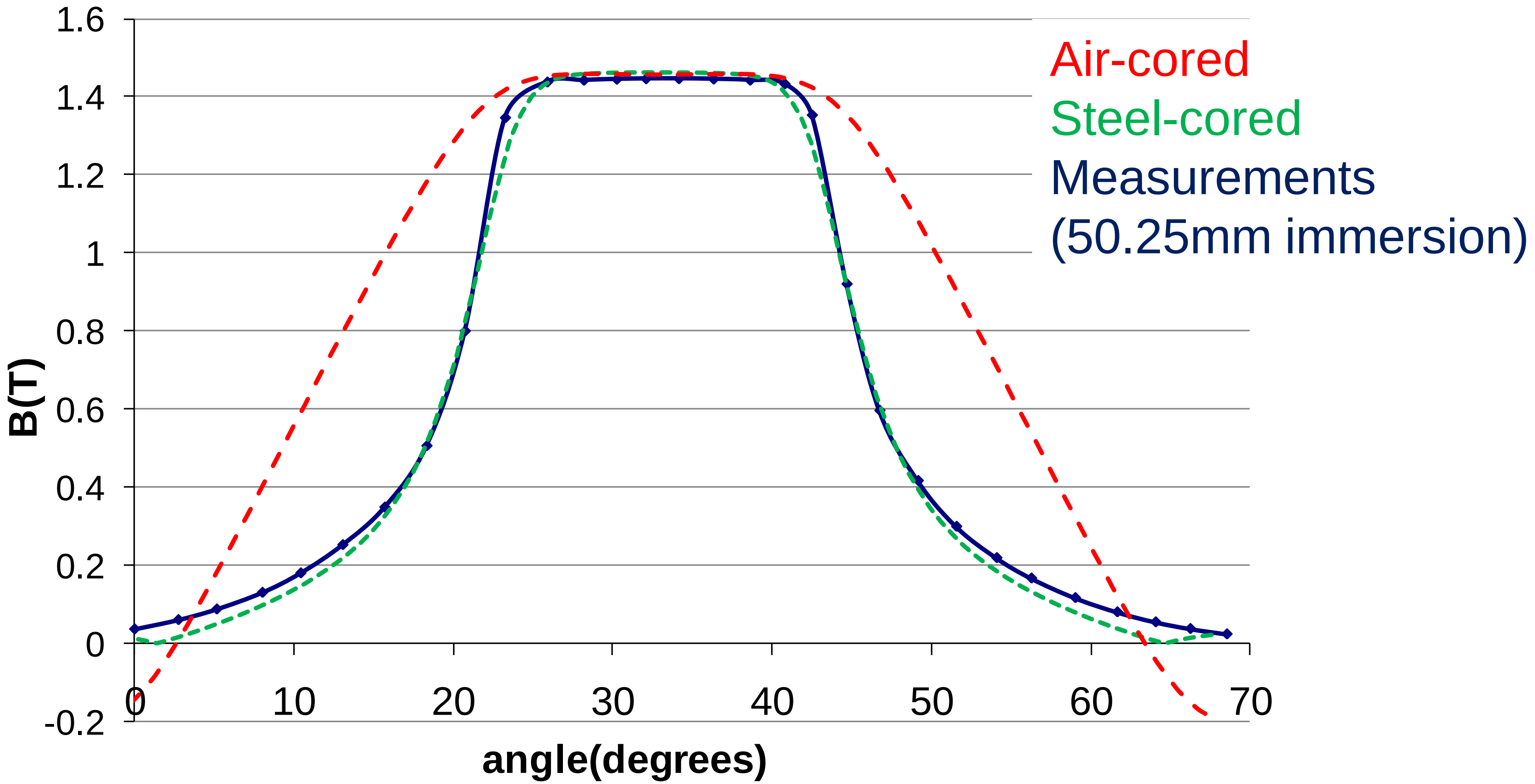
OPERA 3D simulation – spokeless

OPERA 3D is an electromagnetic FEA simulation.



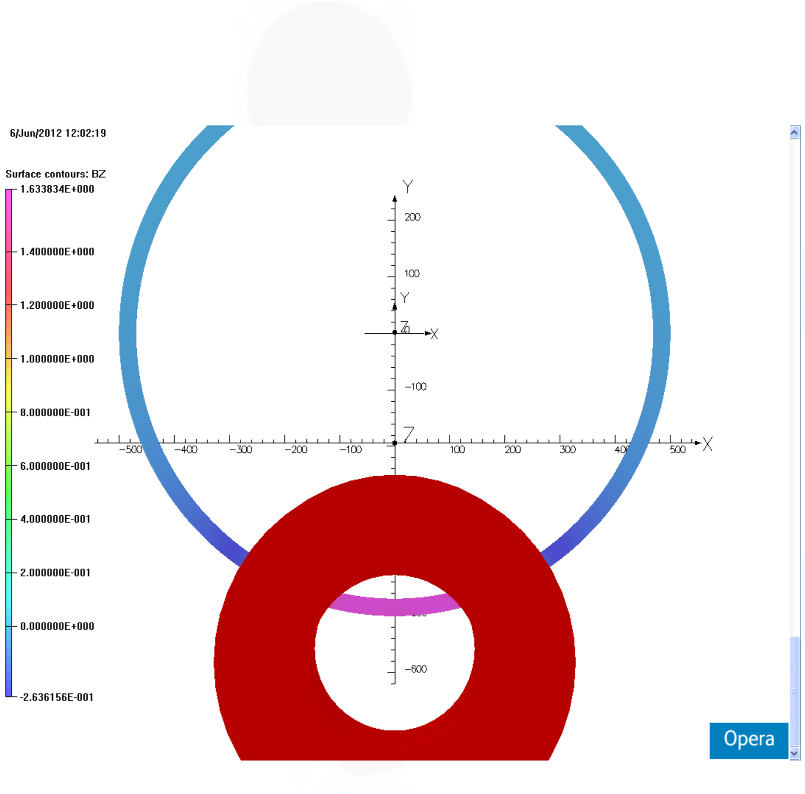
Jim Rochford / Lei Zang's model

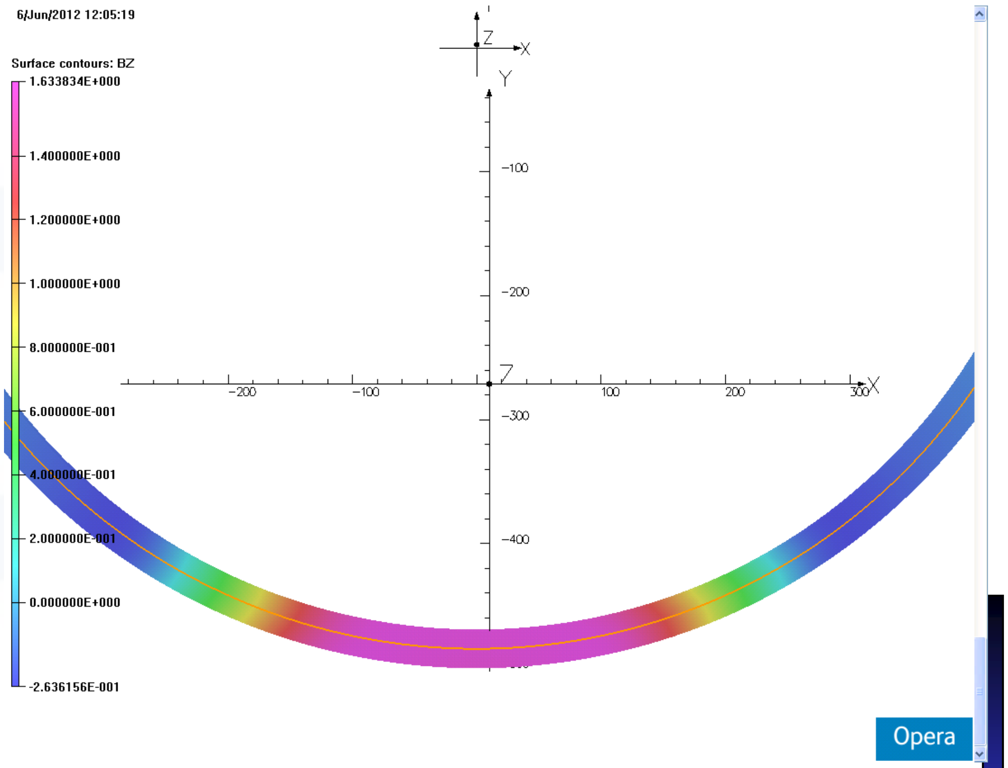
Comparison of air and steel cored ELEKTRA models



20% increase in predicted torque.

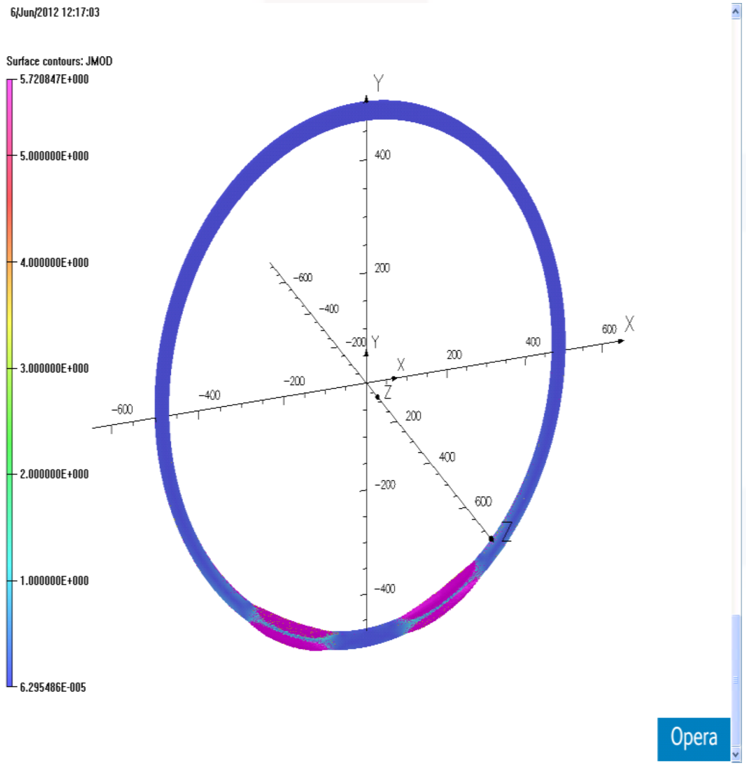
Magnetic field strength

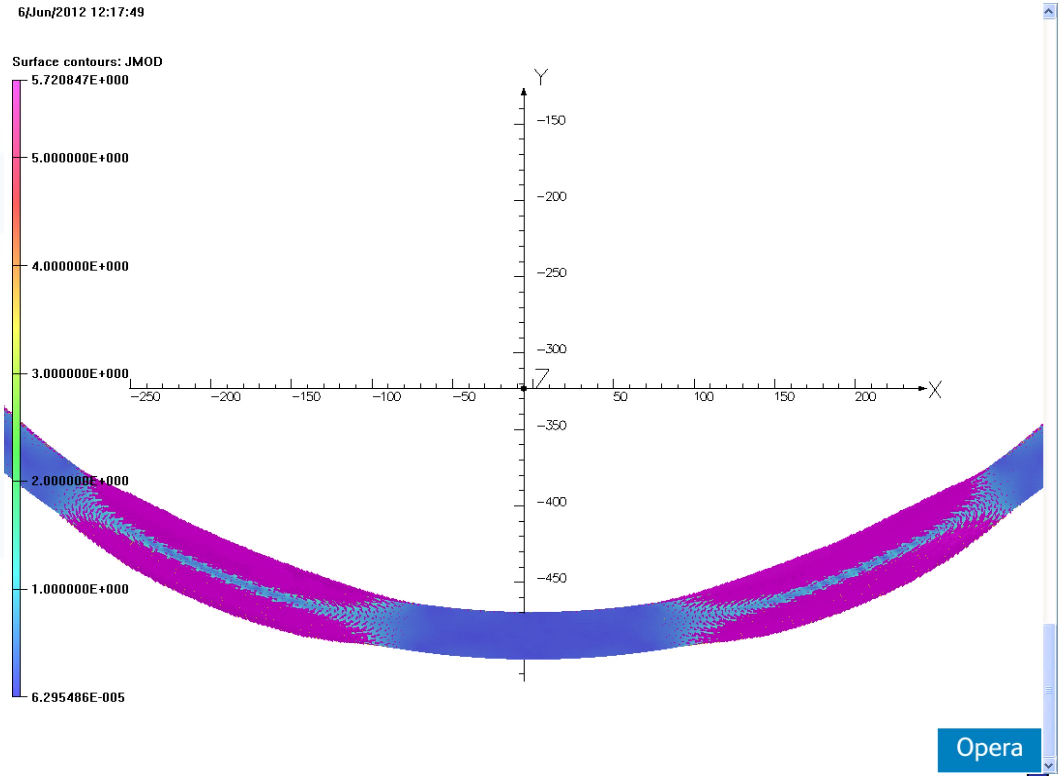




Magnetic field in the z direction (i.e. perpendicular to the plane of the wheel)

Air-cored simulation - eddy currents



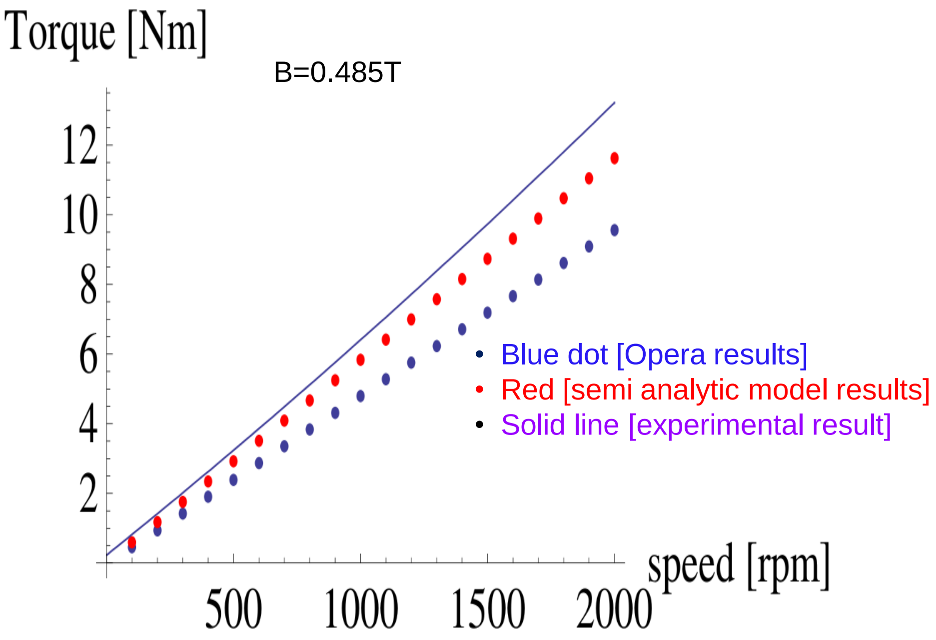


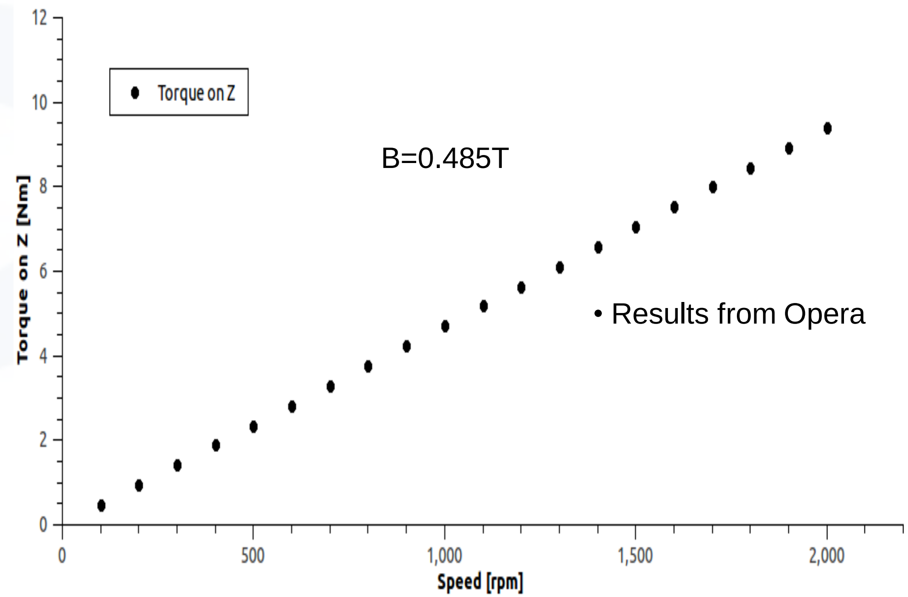
Reproducing prototype results

$$\tau = -rF_x = -\frac{1}{12}\sigma\omega r^2 a_y^2 \int \left(\frac{dB_z}{dx}\right)^2 dV$$

2010 simulations

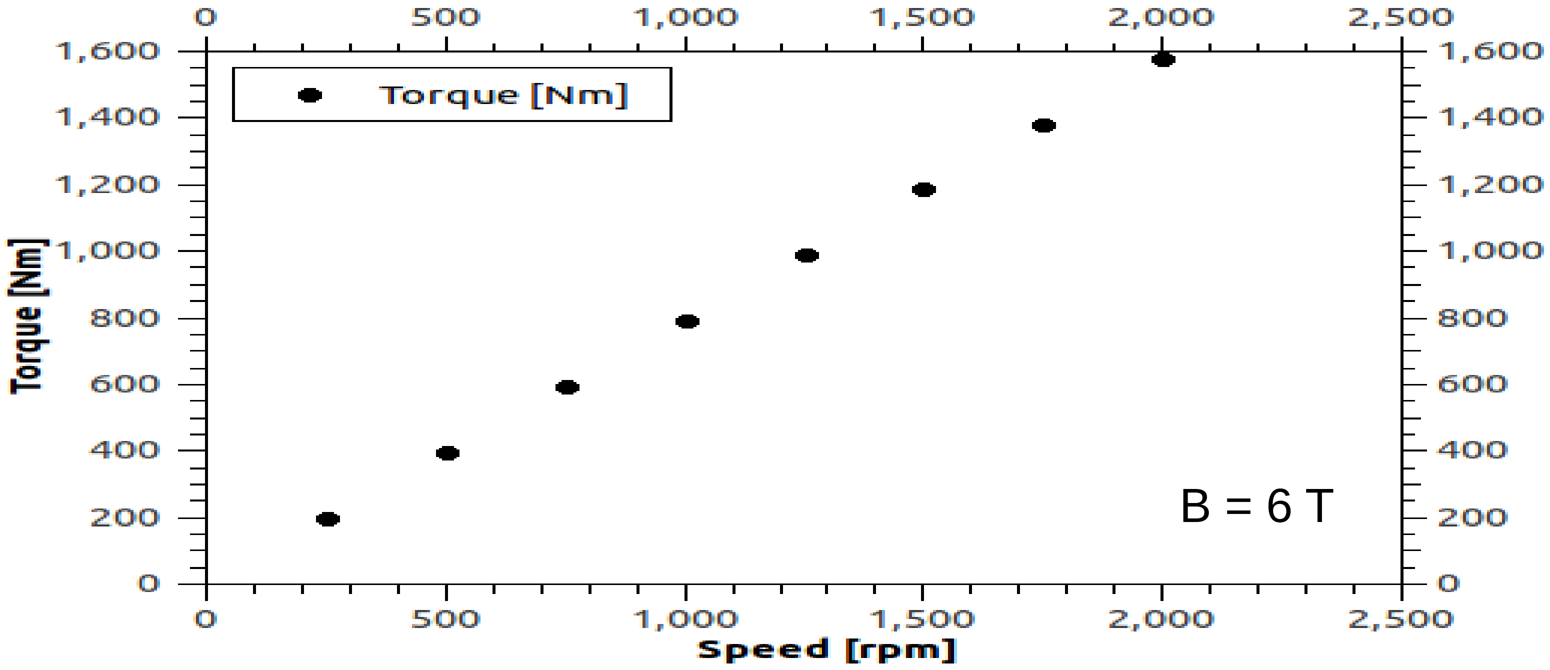
2012 simulations





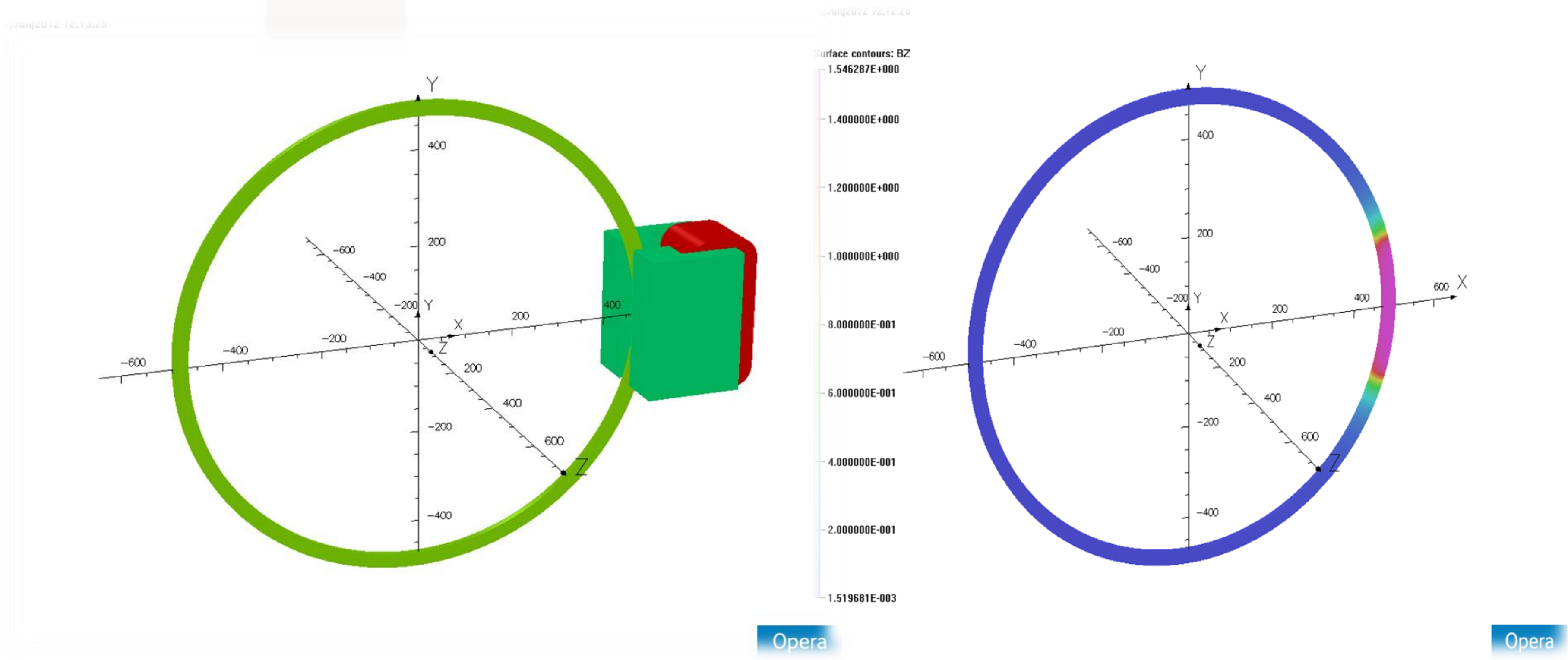
Rim's radial width = 45mm.

Extrapolating to s/c AMD field strength

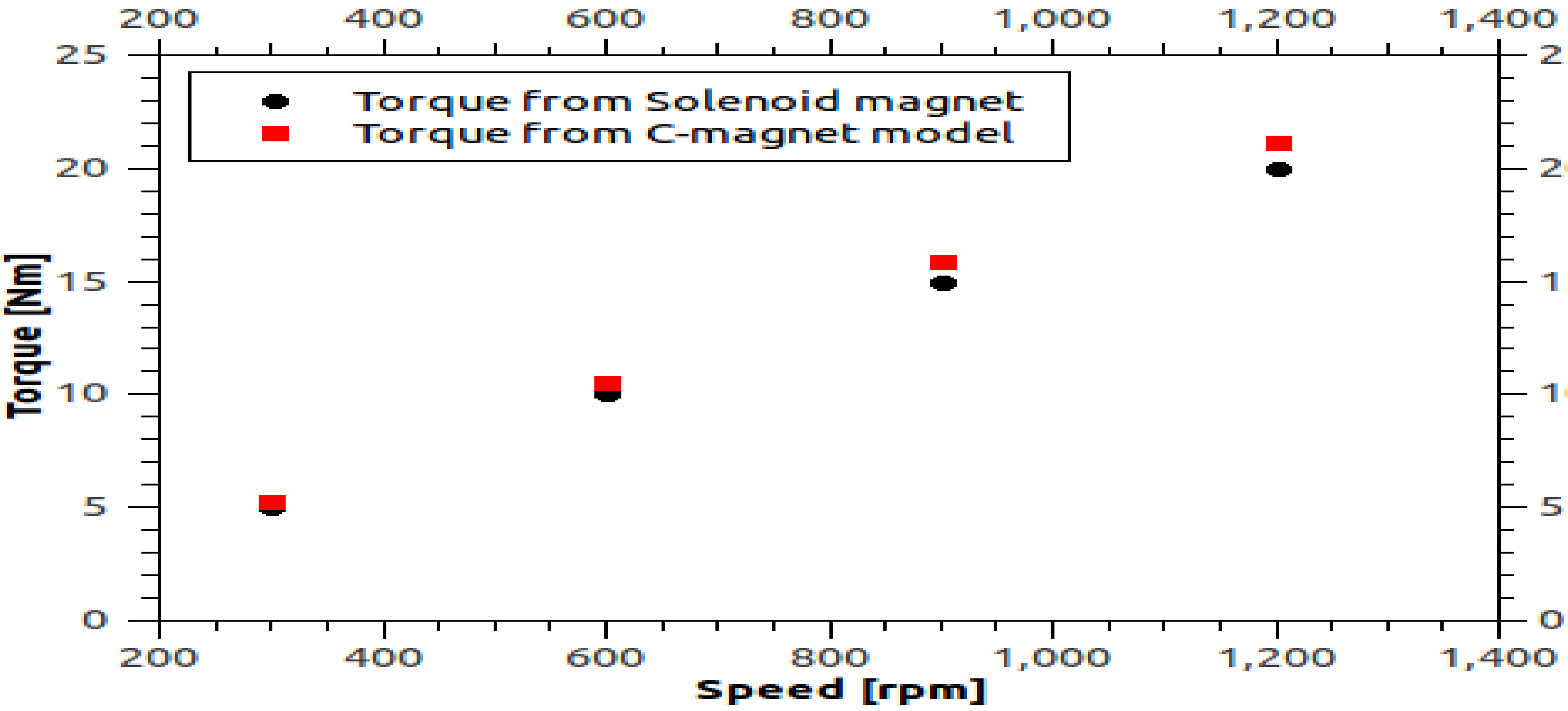


•At 6T, the simulated eddy current heating reaches ~0.3MW.
•Can this be reduced while maintaining high field?
•Jeff Gronberg suggested a fully-immersed target rim.

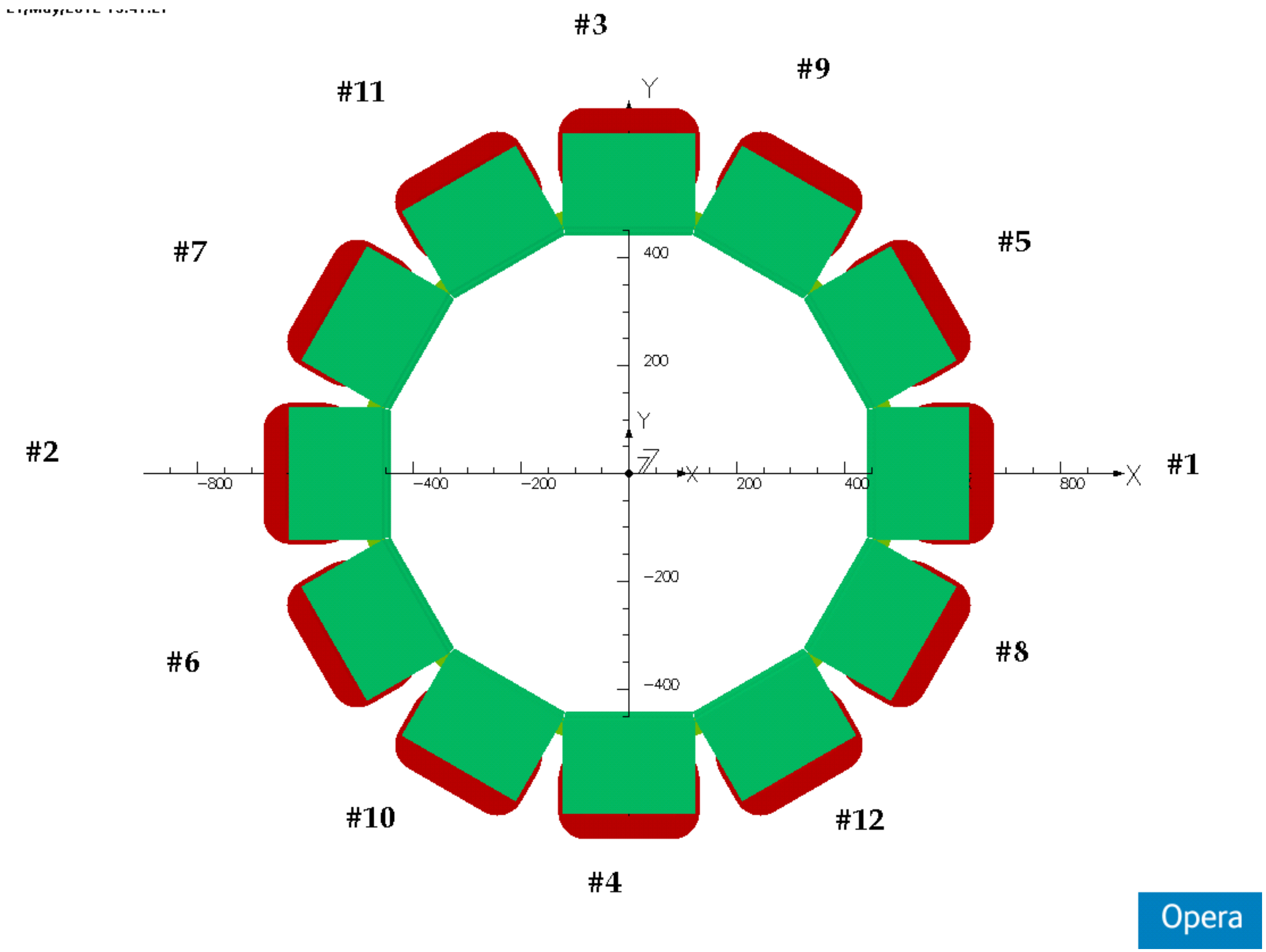
NC C-magnet simulation



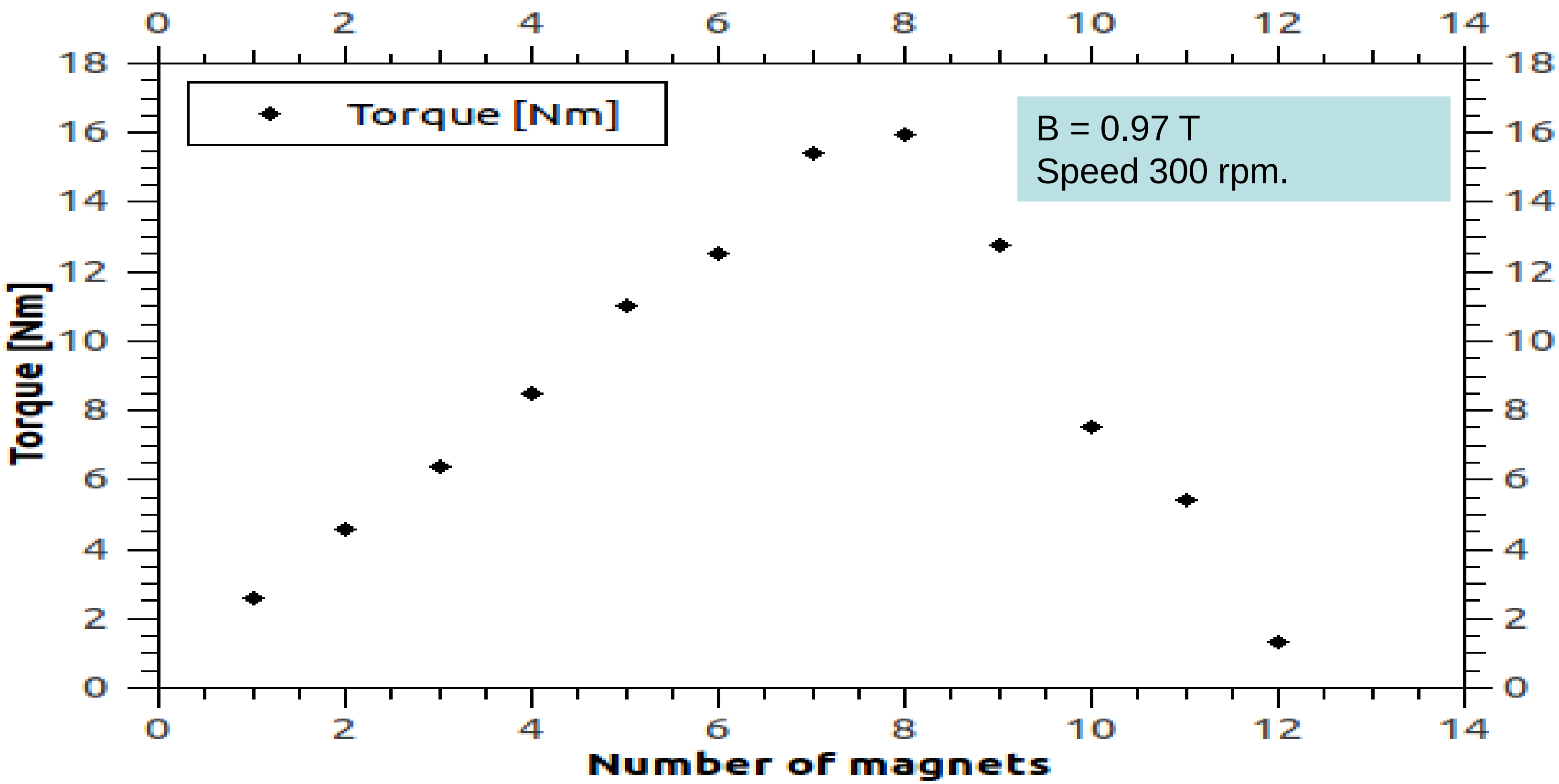
Comparison of original model and C-magnet model



Fully-immersed target model

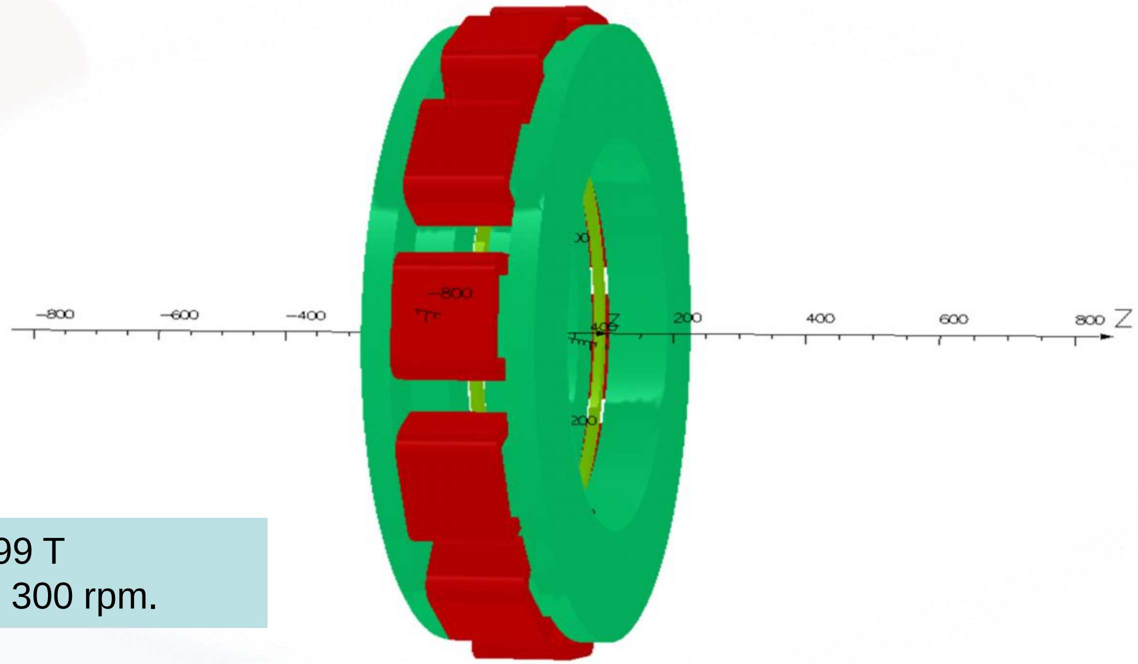


Torque as a function of the number of C-magnets



τ_z when 12 C-magnets introduced reduced to 1.3 Nm

Model with connected iron yoke

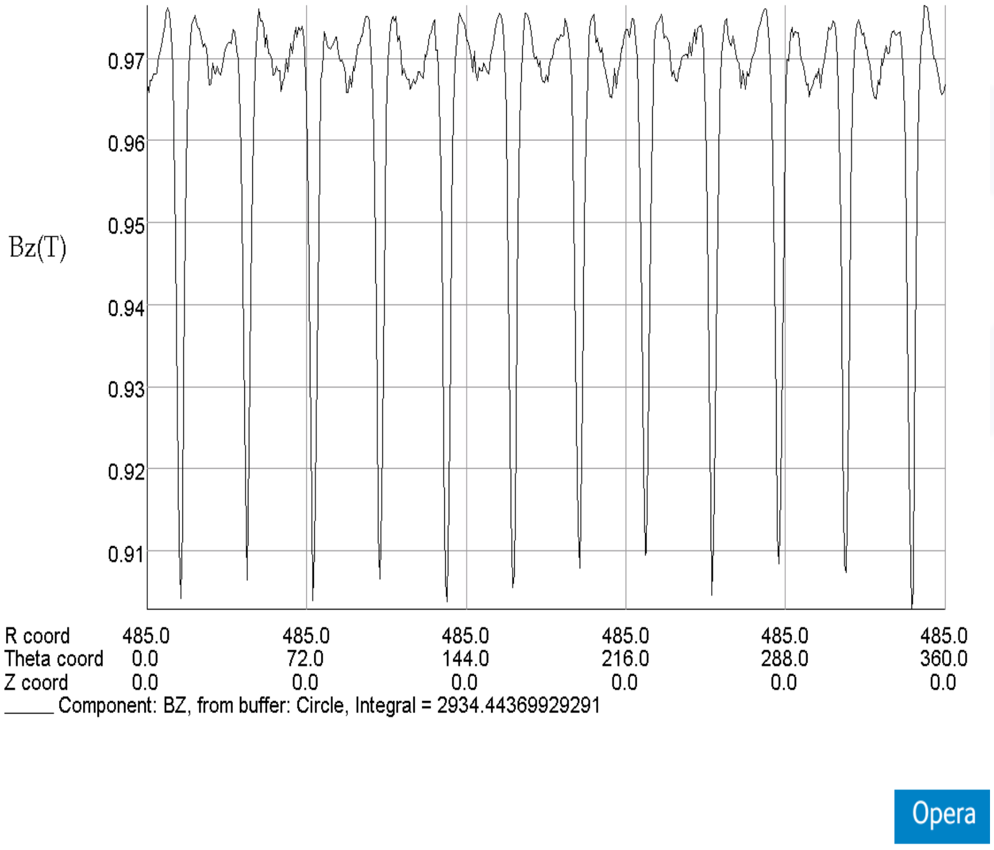


B = 0.99 T
Speed 300 rpm.

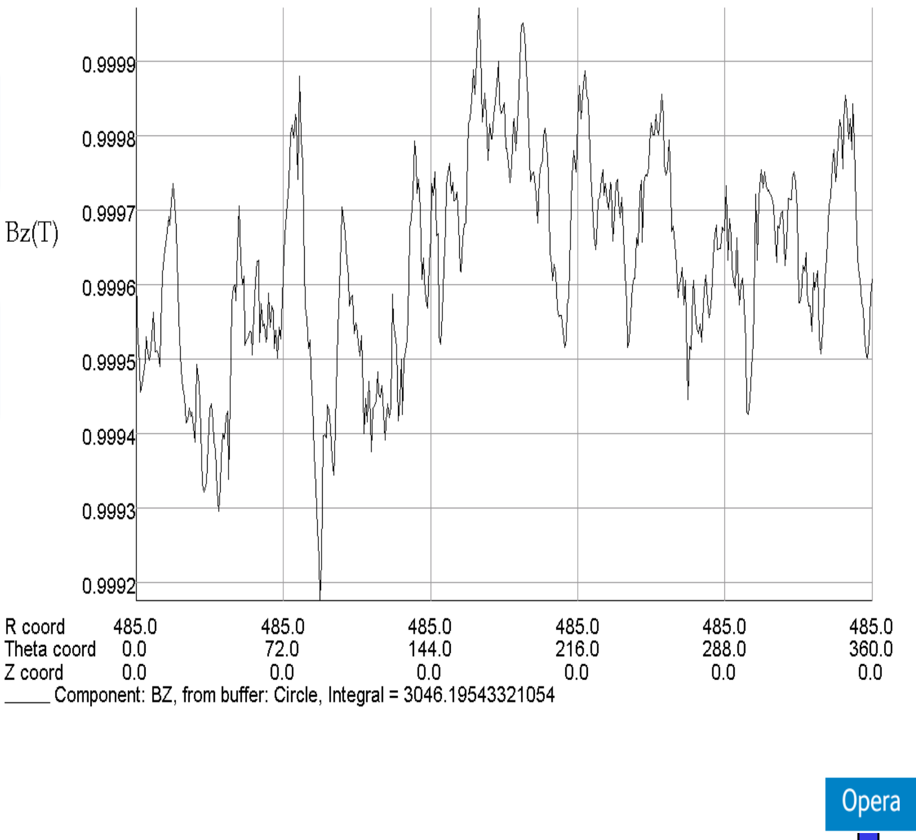
τ_z after the C-magnet models connected reduced to 0.09814 Nm

B_z variation around the wheel

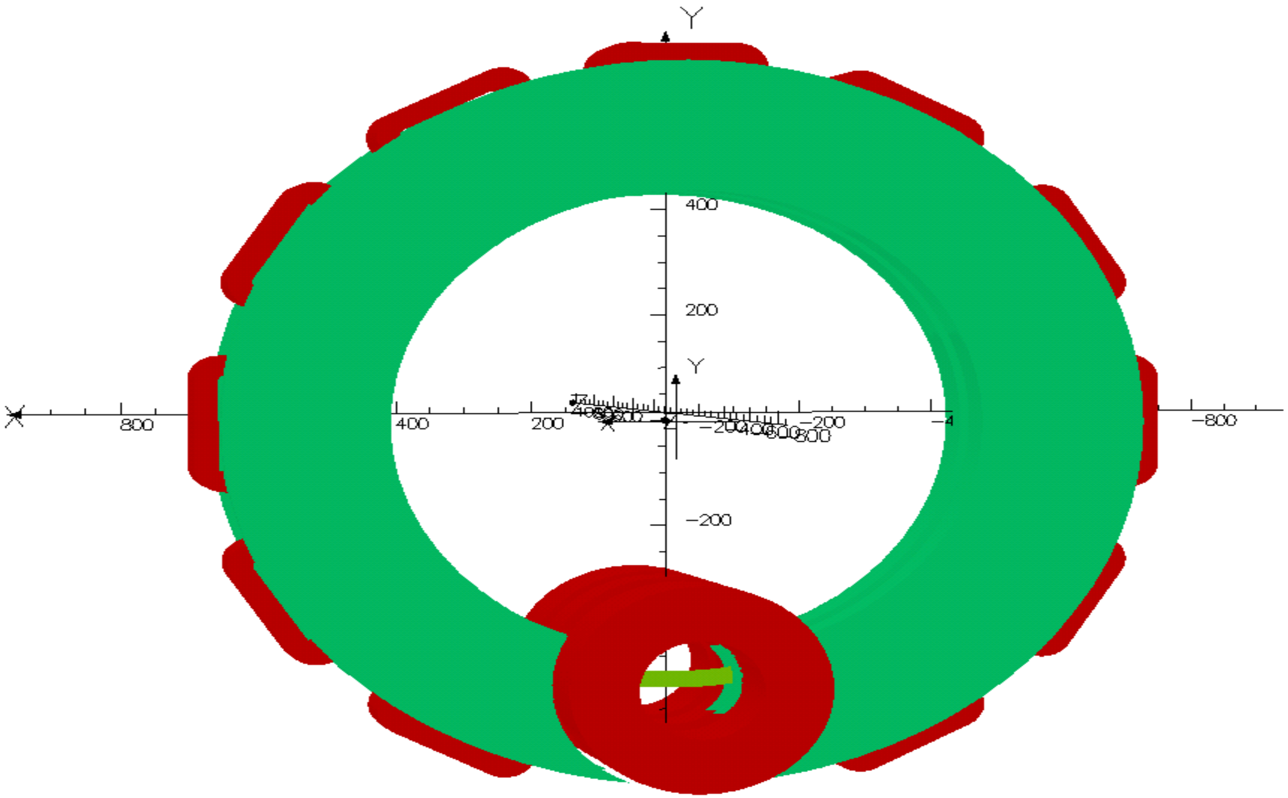
Model without connected yoke



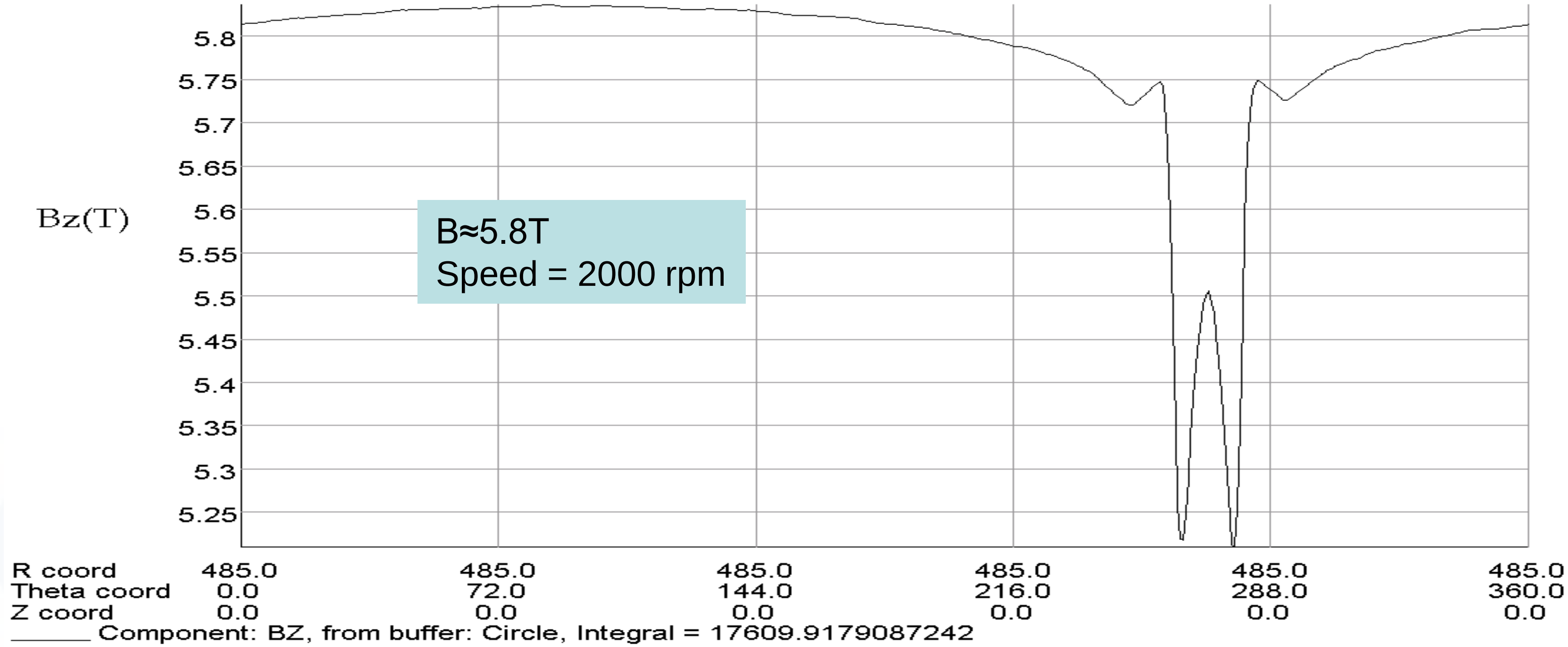
Model with connected yoke



Model including AMD



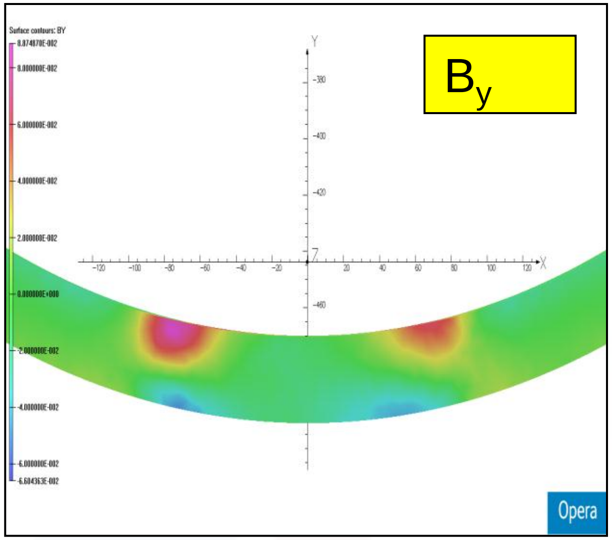
Field variation after introducing the AMD

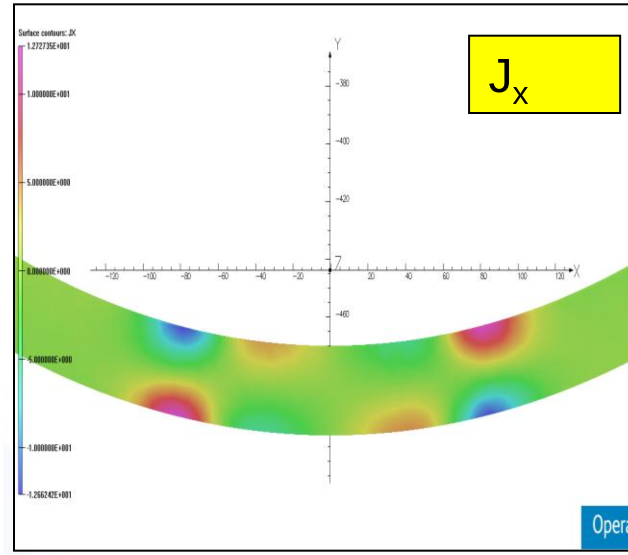


Opera

τ_z =20.41 Nm

Torques out of target plane

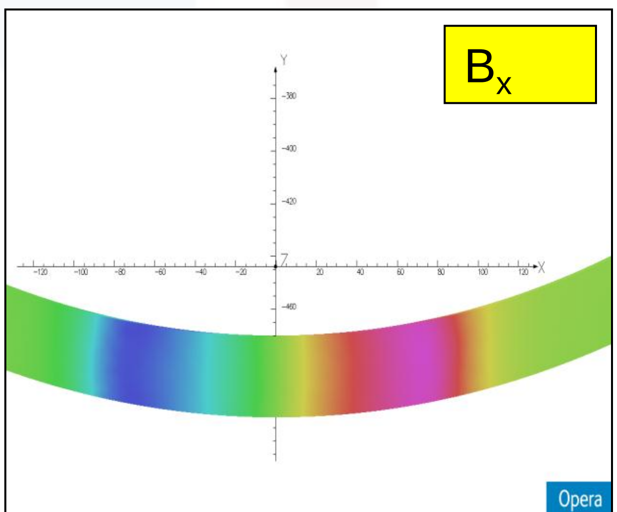


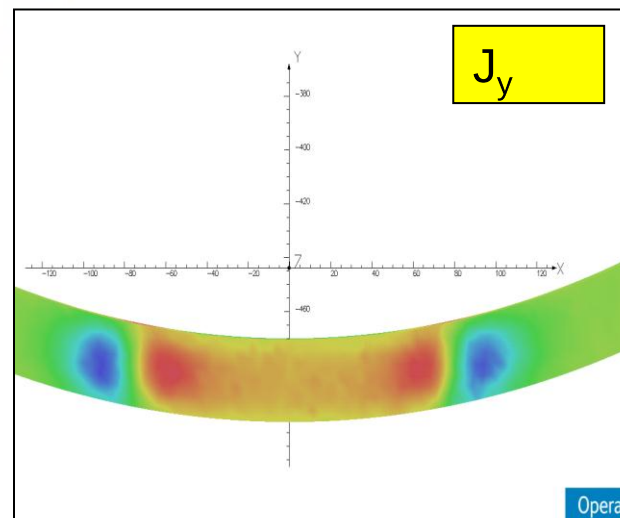


$$F_x = (B_z I_y - B_y I_z)\hat{i}$$

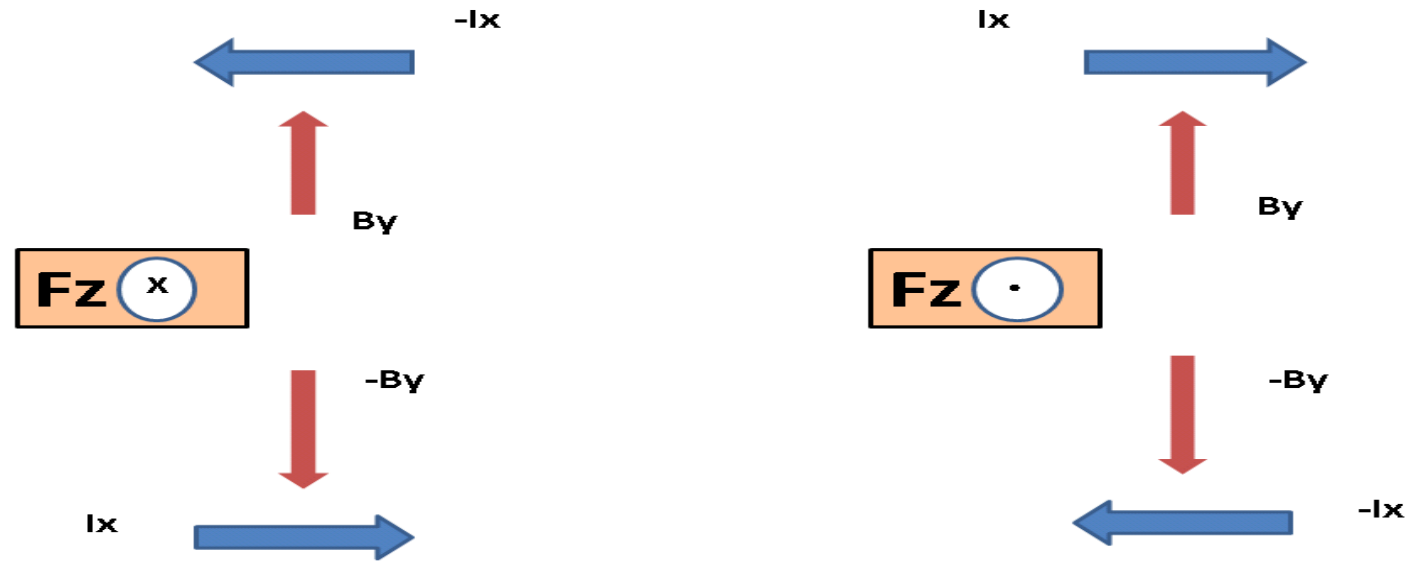
$$F_y = (B_x I_z - B_z I_x)\hat{j}$$

$$F_z = (B_y I_x - B_x I_y)\hat{k}$$



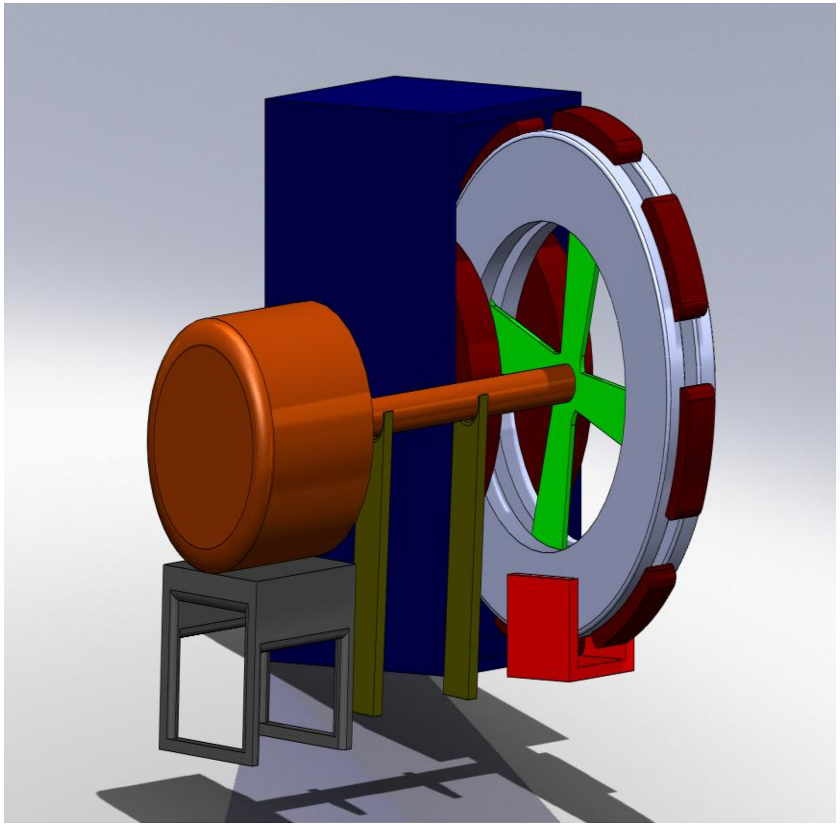


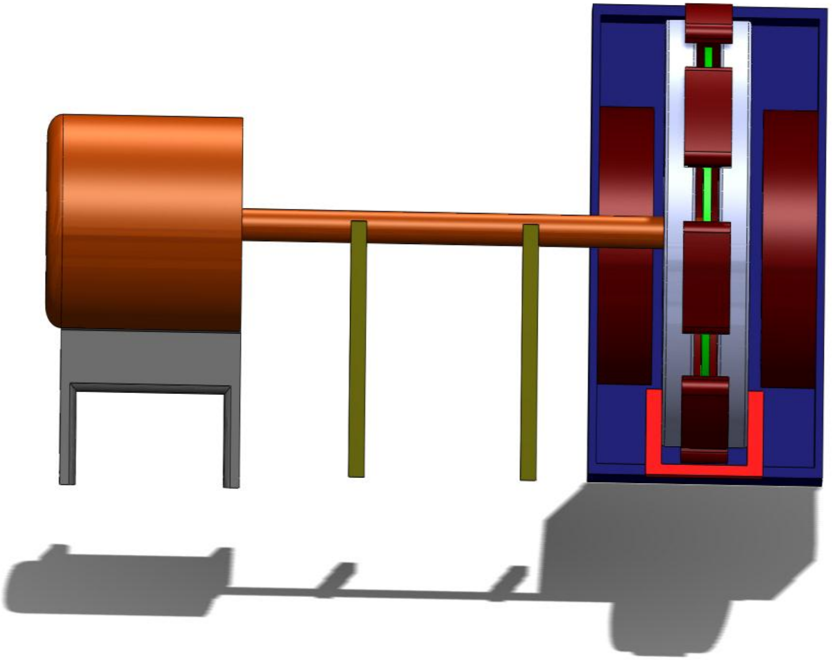
Simple model for τ_y



Direction	Simple model torque	Opera 3D torque
x	11.67 Nm	10.7 Nm
y	11.3 Nm	13 Nm

Mock-up of a fully-immersed target





Conclusion

- In principle it may be possible to reduce the braking torque of 1600 Nm to 20 Nm for a target rotating at 2000 rpm in the field of a s/c AMD with a peak field ≈ 6T.
- A long way from a fully-engineered solution...
- The next step would be to use superconducting windings in the simulation and to look at thermal load, radiation damage, etc