Design of Precision Magnetic Fields for Fundamental Neutron Symmetries

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Introduction: A precision cos(theta) magnetic coil is being developed for an experiment to measure the Electric Dipole Moment (EDM) of a neutron to 1e-28 cm at the Oak Ridge National Laboratory (ORNL) Spallation Neutron Source (SNS). The traditionally magnetic design process involves guessing a reasonable conductor geometry, using finite element analysis (FEA) software to calculate the resulting fields, and modifying the configuration iteratively to reach an acceptable solution. Taking the opposite approach, we developed a method of calculating the conductor geometry as a function of desired magnetic field.

Computational Methods: The Laplace equations are solved for the magnetic scalar potentials using flux boundary conditions determined by field constraints on the surface of the magnet being constructed. The current distribution is then determined from the flow boundary conditions: wires are wound along each equipotential contour of *U* on the surface (flow boundary conditions). The coils can be wound in series if *U* is the same between each contour.

Flux: $$\nabla \cdot \vec{B} = 0 \rightarrow \hat{n} \cdot \Delta \vec{B} = 0 \quad (1)$$

Flow: $$\nabla \times \vec{H} = \vec{J} \rightarrow \hat{n} \times \Delta \vec{H} = \vec{K} \quad (2)$$

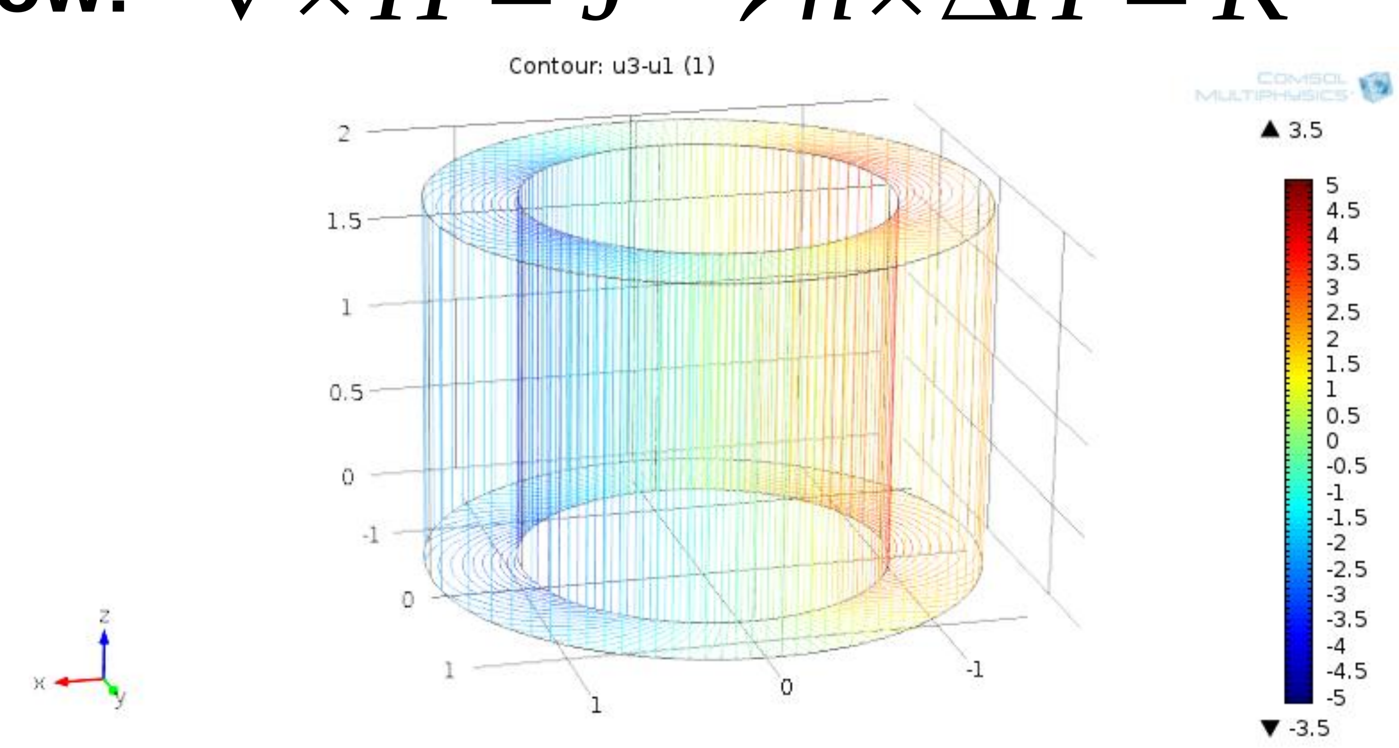

Figure 1. Cos(theta) coil with contour levels.

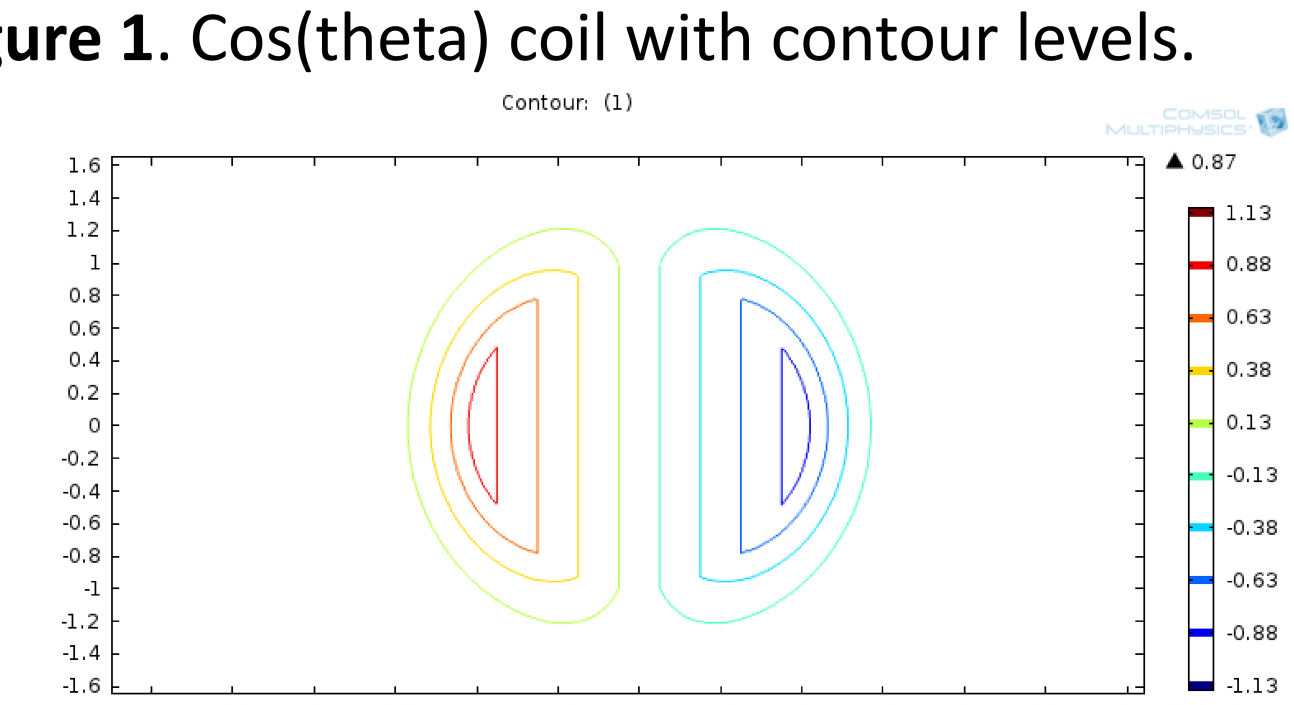

Figure 2. Contour levels for the end cap design.

Results: The MATLAB LiveLink was used to write an interface script for the coil designed in COMSOL. The script extracts the winding path as an ordered list of points and the magnetic field was calculated using the Biot-Savart Law for verification.

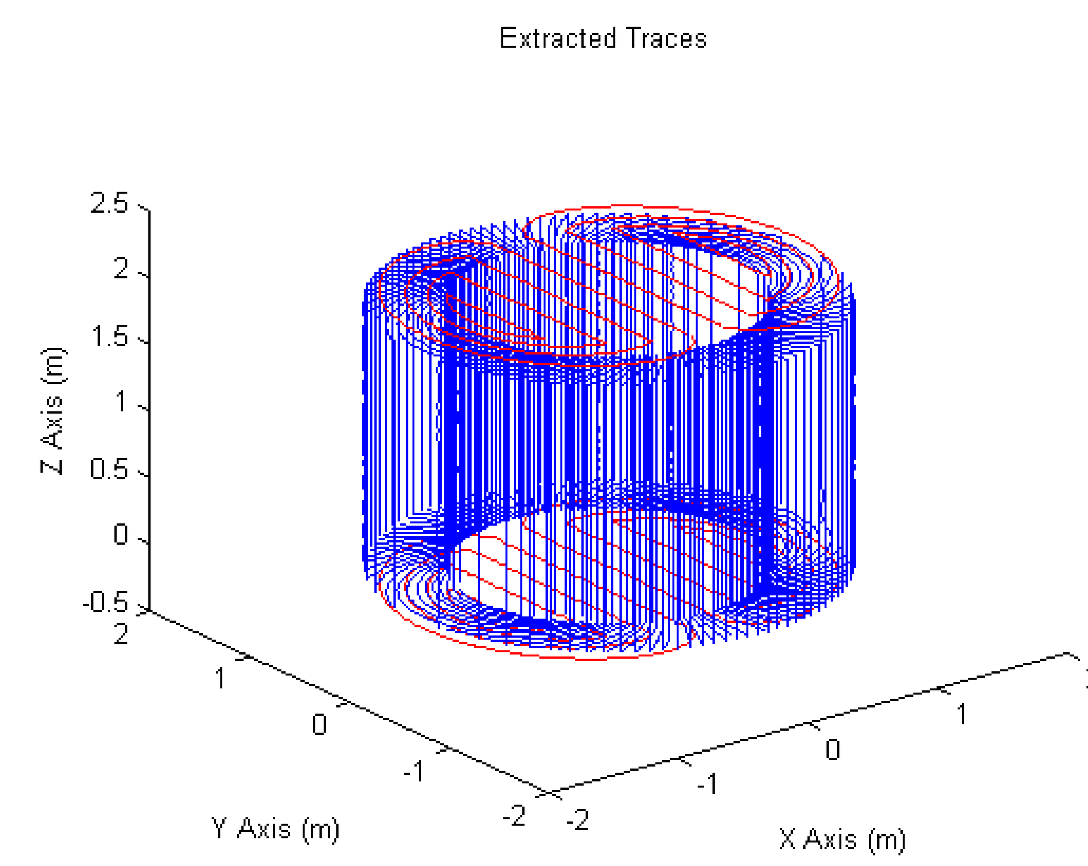

Figure 3. Extracted traces from coil.

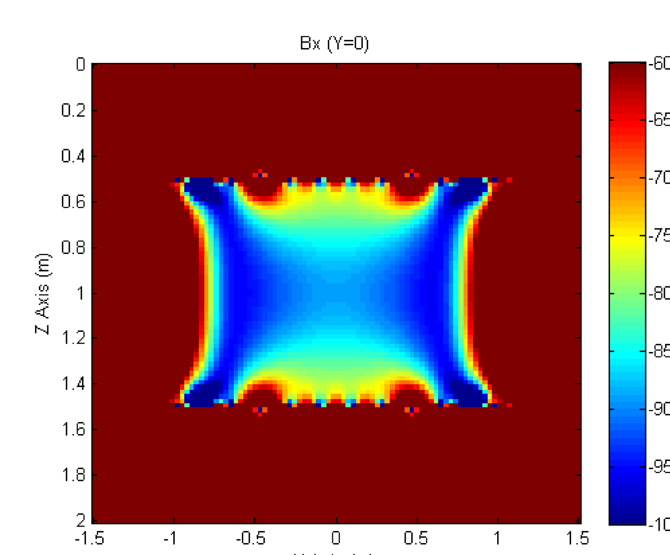

Figure 4. B_x, end cap.

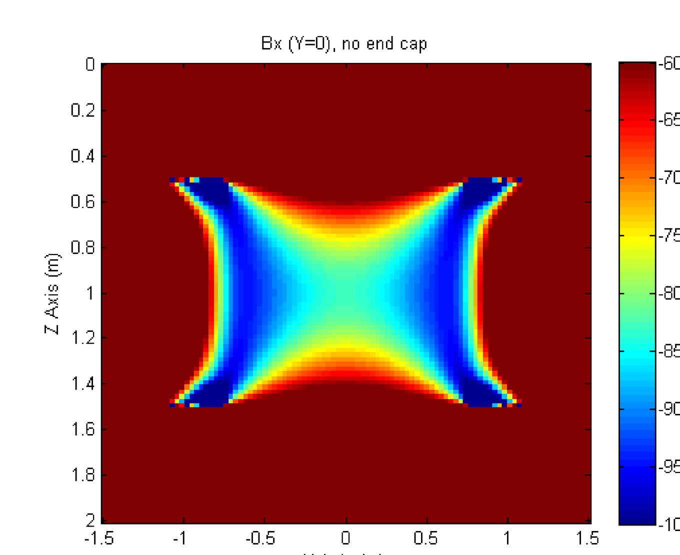

Figure 7. B_x, no end cap.

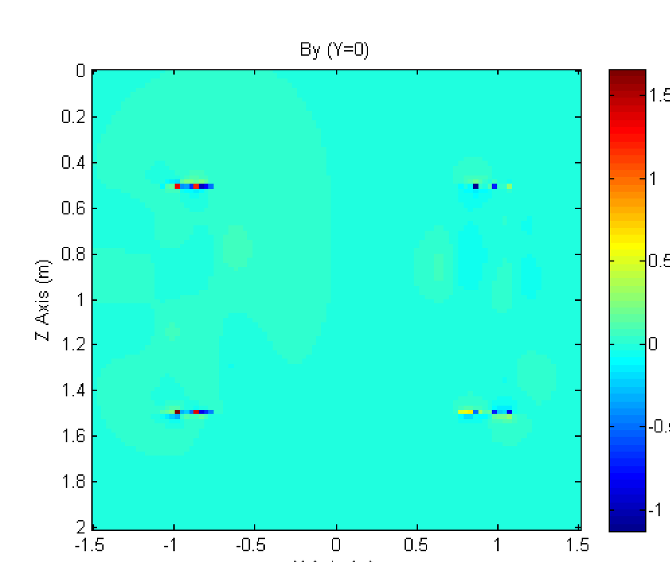

Figure 5. B_y, end cap.

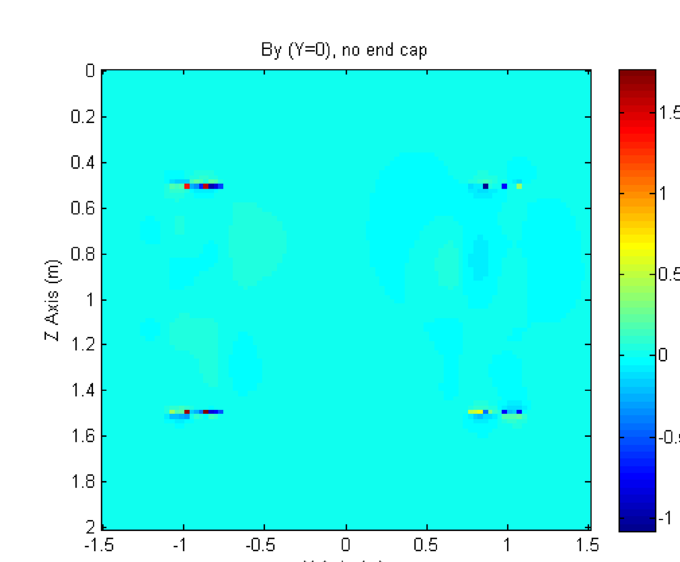

Figure 5. B_y, no end cap.

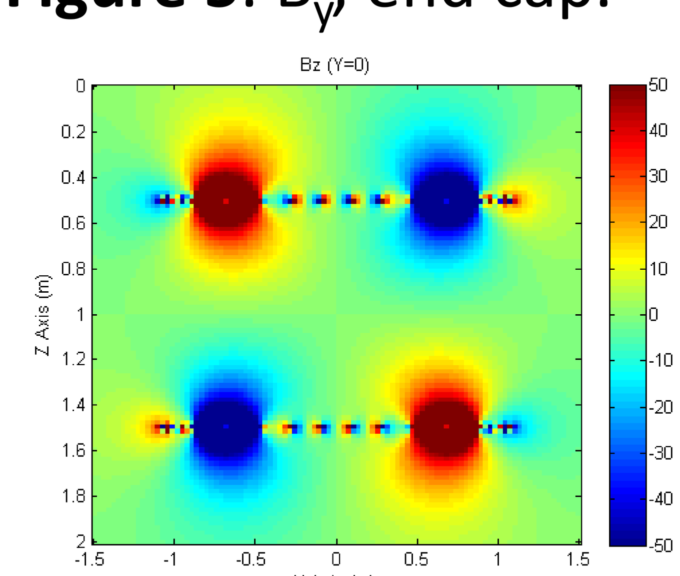

Figure 6. B_z, end cap.

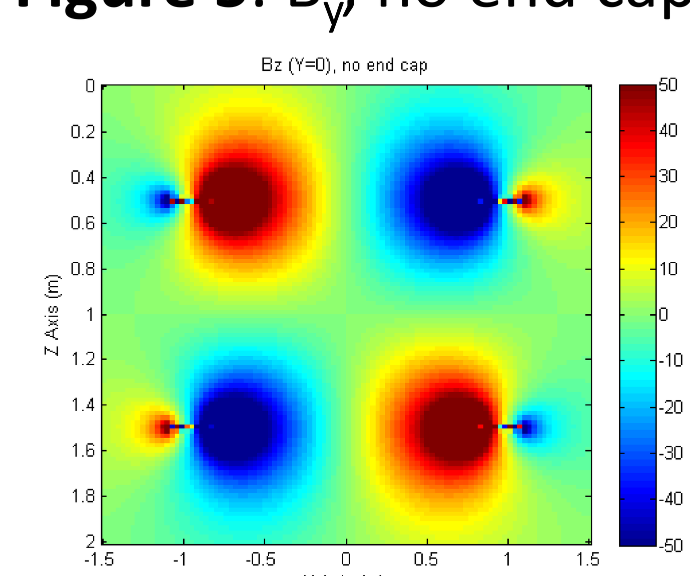

Figure 6. B_z, no end cap.

Conclusions: The cos(theta) coils was successfully designed and simulated in COMSOL. The MATLAB LiveLink proved to be effective in the verification of the coils magnetic field. This method can be used to design surface current magnets.

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