Designing a Uniform Magnetic Field for nEDM Experiments

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Introduction

According to the Big Bang Theory, equal parts of matter and antimatter should have been created in our Universe. Now, it is predominantly matter. Understanding the differences between particles and anti-particles through CPT symmetry could lead to insight into our existence and reshape the Standard Model of physics. This matter – antimatter imbalance can be explained with the detection of a non-zero electric dipole moment within the neutron (nEDM), which violates these symmetries. To detect an nEDM, an extremely uniform magnetic field is required because neutrons are hypersensitive to magnetic fields (1, 2, 3). The main goal of this project is to design a uniform magnetic field that will be used measuring the nEDM. This magnet will be a double cosine theta coil. The design includes a cylindrical, double layer aluminum skeleton that will serve as the base of the magnet and skins to surround it. These skins will contain clips which will secure the wires in place and make the field more uniform. Once the design of the magnet has been finalized and all components have been 3D printed, the magnetic field can be mapped using a robotic mapper and MATLAB. This could then be used to understand what adjustments would need to be made on a design level to improve the electromagnet's uniformity.

References

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2. Caspi, S., et al. (2014). Canted-cosine-theta magnet (CCT)-a concept for high field accelerator magnets. *IEEE Transactions on Applied Superconductivity*, 24(3), pp. 1-2.
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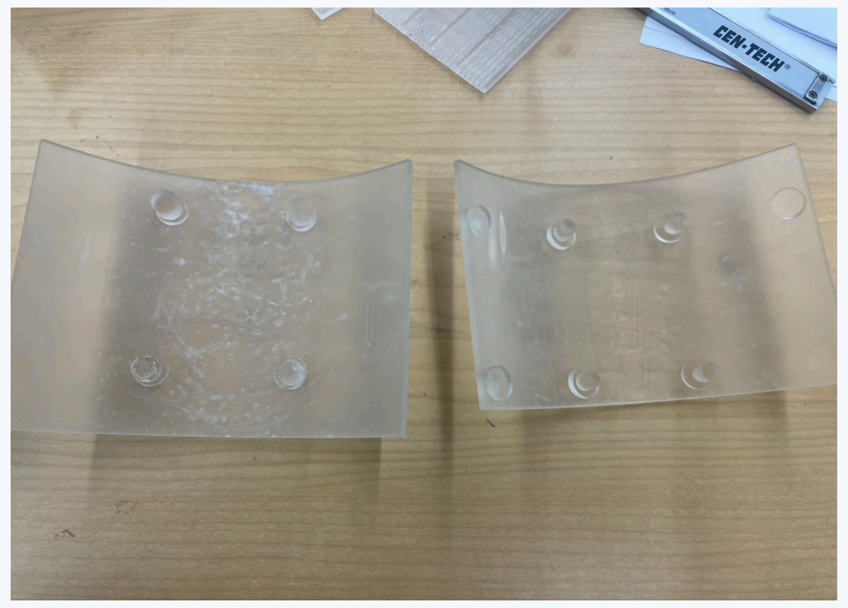
Acknowledgments

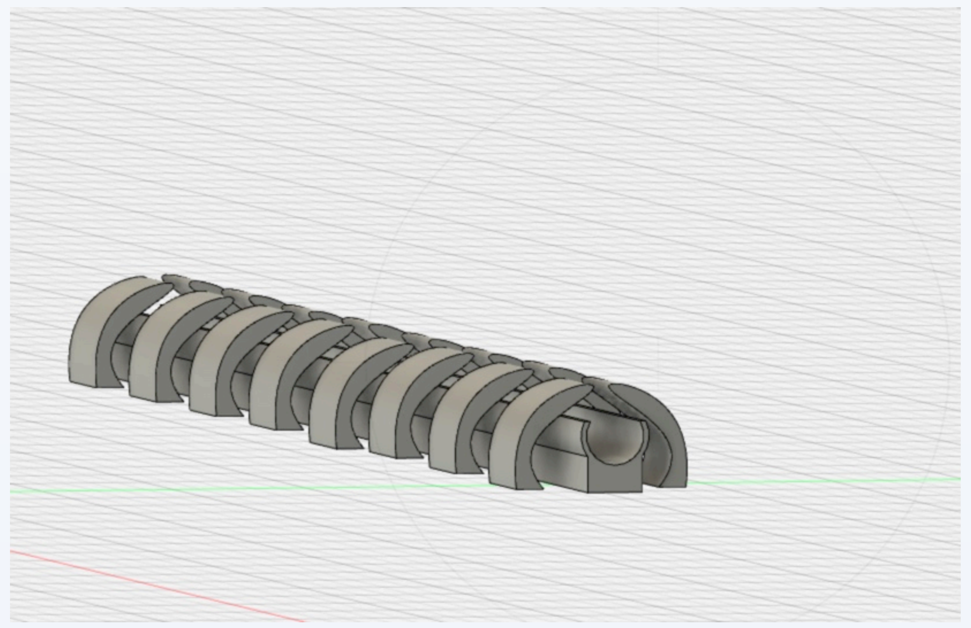
- The University of Kentucky Department of Physics and Astronomy
- Funding by the Summer Undergraduate Research Fellowship
- This work is funded in part by the National Science Foundation under grant PHY-1950795
- National Science Foundation REU Program

Procedures & Results

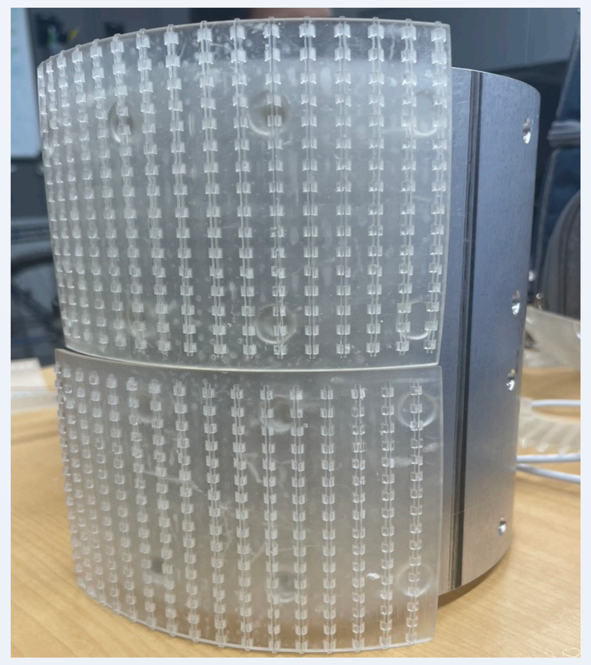
1) Resin skins were 3D printed to cover the base of the magnet (the aluminum skeleton). Based on previous prints and designs, the dimensions of these skins were adjusted to better fit around the skeleton.



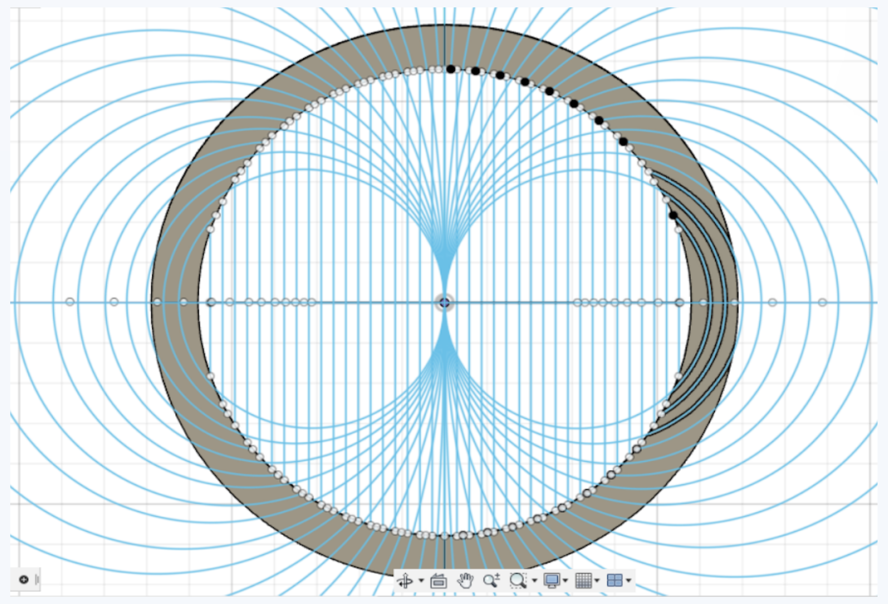
2) Clips were designed to hold the wires, that would coil around the magnet, in place. This design consisted of a trench and clips covering but not attached to the trench.



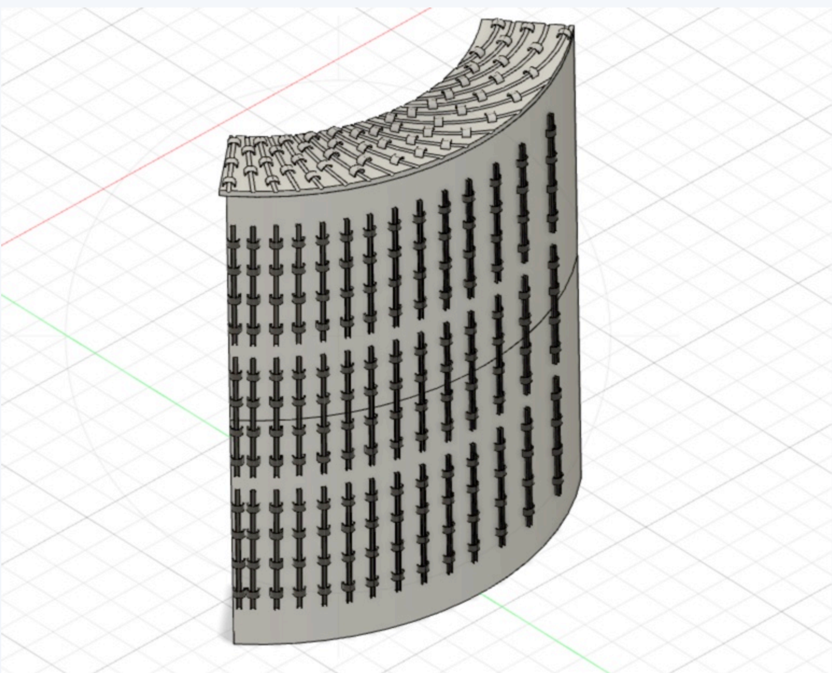
3) Multiple prints were run through the 3D printer to test how the clips worked when attached to the skins. Wire was snapped into the clips to test durability.



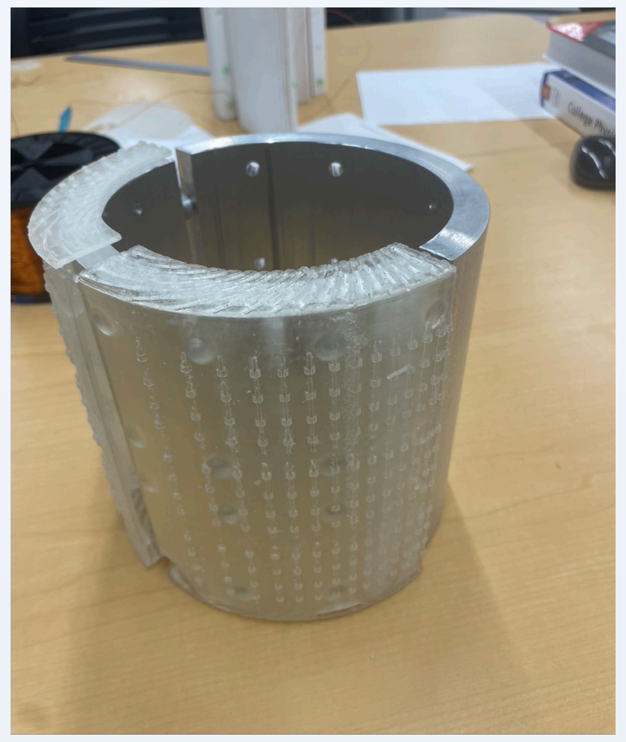
4) Equipotential lines were drawn in Fusion 360 to map out the exact placement of clips on the skins. The paths were made using the 3-point arc tool and are equally spaced apart. These lines represent the exact path of the wire around the coil.



5) A final design of the skin included clips placed exactly where the equipotential lines were drawn.



6) The final 3D print of this project consisted of clips to secure wire on specific winding paths. Due to the size of the skeleton, the skins were printed in ¼ sections.



Conclusions

We conclude that it is important to test different dimensions of the designs in small increments to accommodate the low resolution of the printer (0.1 mm). For instance, we were able to keep the wires in place on the second print by pushing the clips closer together over the trench by an estimated amount of ~ 0.03 mm in Fusion 360.

Some segments of the prints were broken off during construction or simply did not print at all. Printing at higher resolutions would fix this issue because the printer neglects elements of the design beyond certain size thresholds (>0.05 mm resolution)

Thus, printer limitations rather than internal design, was the primary contributor of failed prints.

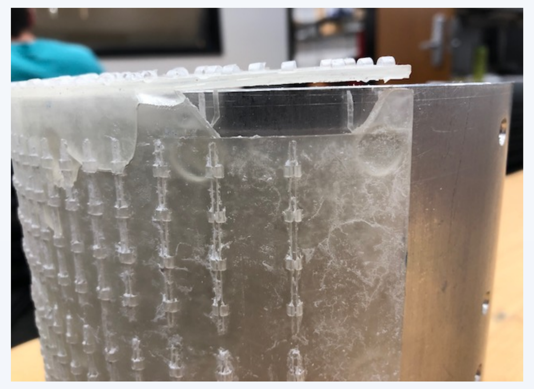


Figure 1: An example of the 3D printer producing an incomplete print.

Figure 2: An example of a print breaking during the testing process.

Next Steps

- Clips on the final design print should be altered because they break easily and are difficult to clip wire into
  - Clips can be made longer and slightly thinner to stabilize the design
- Complete the designs for skins that will line the inner walls of the skeleton
  - Adjust skin curvature based on the skeleton
  - Align clips on the inner skins based on the equipotential lines
- Print skins to completely cover the skeleton
- Wind the coil and map the magnetic field using the robotic mapper