Developing Instrumentation for Magnetic Field Measurement

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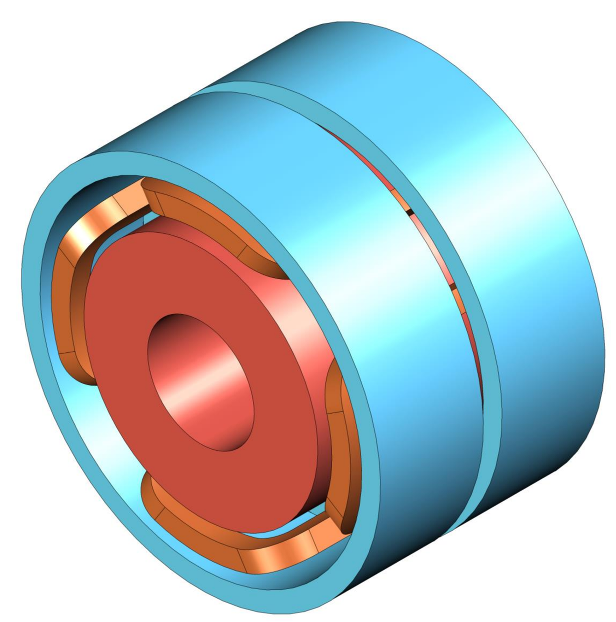
Background

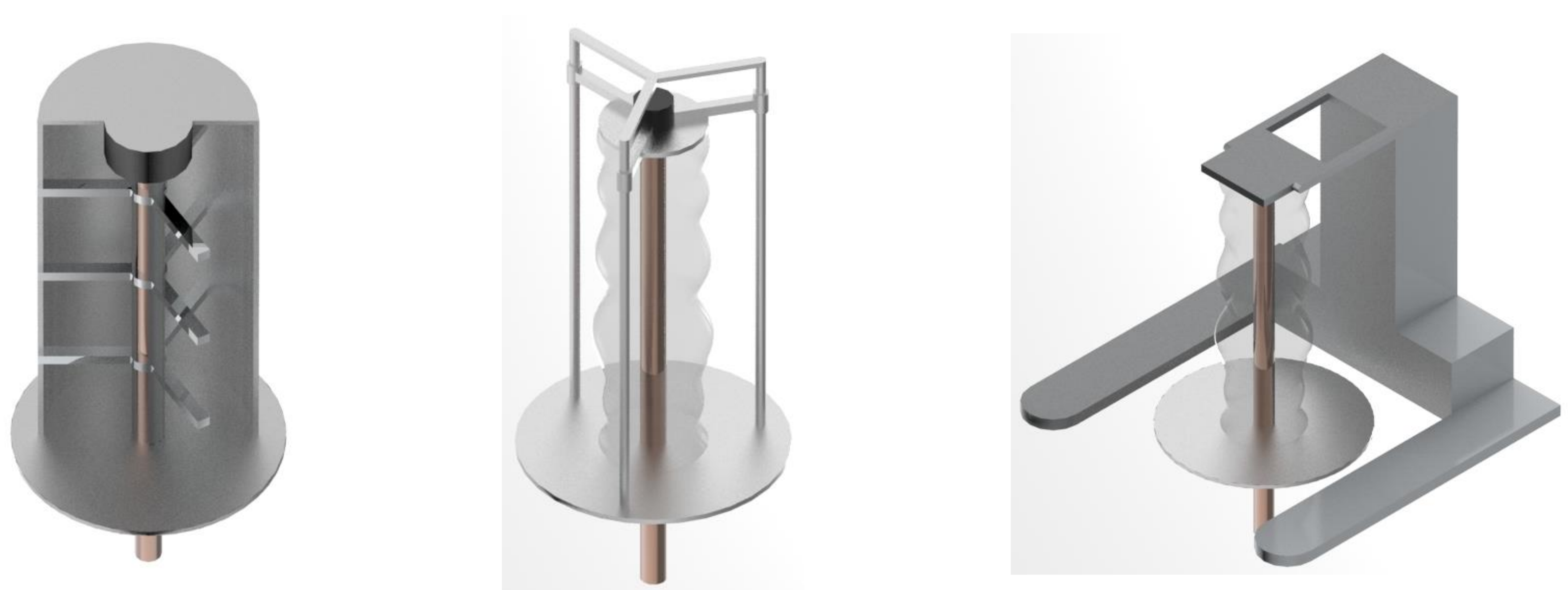
In synchrotrons and linacs, magnetic fields are used to shape and steer particle beams. PIP-II will use superconducting focusing lenses in its cryomodules, all of which need to be validated before use. To test whether a lens is functioning properly, its field needs to be accurately mapped in its working environment, i.e. high vacuum at liquid helium temperature (4 Kelvin). This project's goal is to design the mechanical components of such measurement system.

The first SSR1 cryomodule, which includes accelerator cavities and magnetic lenses, all cooled to 4K.



A focusing lens, which includes an axial solenoid (blue), four transverse magnets (orange), and a beam pipe (red).

Design Process



Several concepts were developed to address the structure and motion portion of the system, which fell into three general categories: (from left to right) a rigid tower with some moving parts within the vacuum, structural legs along which an open-air motor can move a plate attached to a vacuum bellows, and a vacuum bellows paired with an off-the-shelf positioning stage.

While deliberating on which concept to pursue, we were able to further the design and analysis of common components, namely the vertical positioning shaft and probe head. Considerations for the shaft include: weight, flexural rigidity, heat capacity, radiative heat output, and resonance modes. The probe head was designed to maximize spatial resolution while minimizing redundant measurements.

Criterion	Weight	Rigid Tower	Bellows & Legs	Bellows & Stage
Manufacturability	10	1	2	3
Materials Cost	10	2	3	1
Labor Cost	10	1	2	3
Calibration	15	1	1	3
Maintenance	5	1	3	3
Service & Upgrades	15	1	2	3
Reliability	10	3	2	3
Footprint	15	1	2	3
Novelty/Fun	15	2	3	1
Weighted Total:	**105**	**50**	**75**	**88.33333333**

The final concept selection was based on several practical engineering criteria, ranging from ease of manufacturing to degree of fun involved in developing the design. As is common, the least fun option won.

Next Steps

With conceptual design wrapped and the analysis either completed or coded to plug and play, what remains is finalization of the probe head, parts specifications, and final checks. The mechanical system could theoretically go into the procurement phase before the end of the year, though electrical and controls designs are separate projects that also must be completed.

This three-tier probe head has nine Hall probes in different positions and orientations to capture the 3-dimensional magnetic field as it travels down the axis of the lens.

References

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