

# **Rotating Target System**

## **Review**

**D. Keller, July 30, 2021**

# Behavior of HIP

- Even with e-beam we know what some of the radiation damage processes are but not all of them
- The manifestation of these processes into 'bad' paramagnetic centers is beam energy and target temperature dependent with rate effects involved as well
- The photon beam production of paramagnetic centers may not be directly proportional to heat load as the 'bad' centers are less likely to be produced in the front of the target and almost only comes from pair production and e-Compton scattering at lower energy further in the target
- We should expect many more lower energy processes to terminate in the target that are not producing as many 'bad' centers as seen in electron beams
- But still mostly an open question when trying to consider numbers, a more sophisticated MC-effort maybe worthwhile to understand the profile of radiation damage in needed dimensions of this type of target (at least down the road)

# Need New Specialized Target insert for CPS

Why is this needed?

- **Depolarization due to radiation damage**
- Radiation damage depletes the polarization mechanism pathway for DNP
- Production of free radicals is the leading cause of target maintenance and over head time during production
- **Depolarization due to local beam heating**
- Local hot-spots caused by interfacial thermal heating
- This depolarization is just the beam spot is very hard to measure as the rest of the sample seen by NMR is cooler

# So far Studied

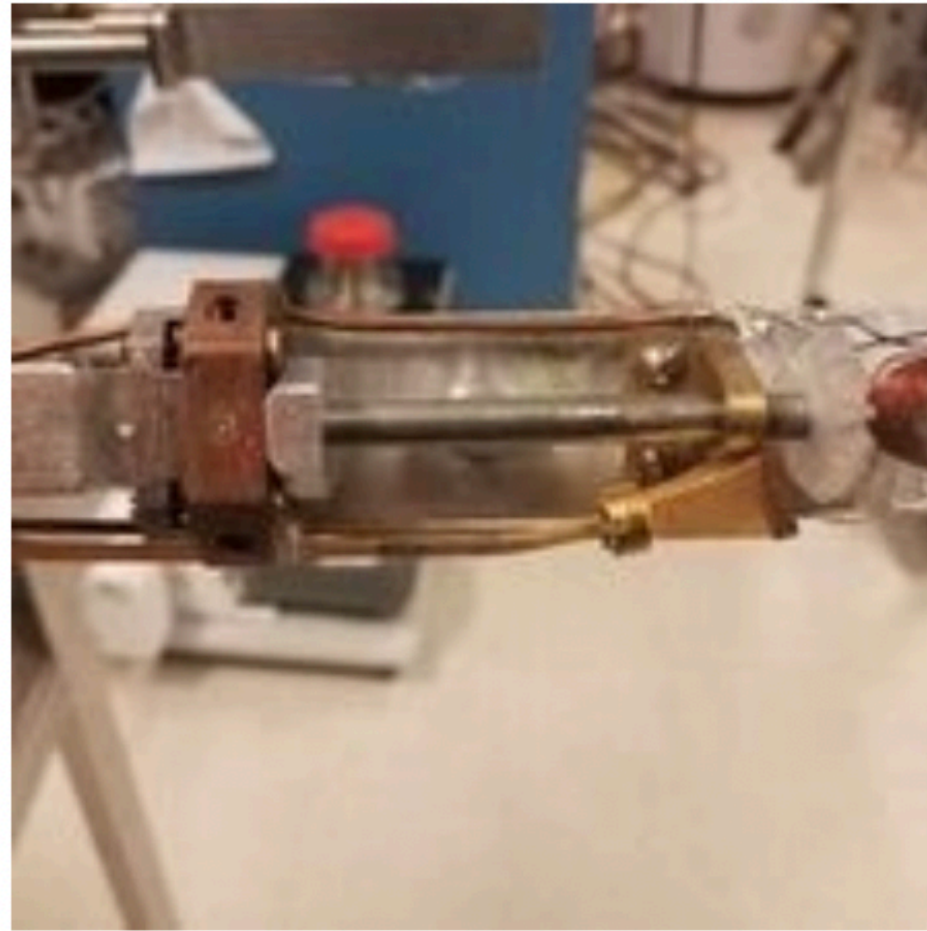
## At UVA

- Mechanical Rotary Vacuum Feed Through
- Geared Cups, size of cup can change but not necessary
- Use combination of already used target position actuator and rotation
- Connected Motor at the top of cryostat
- NMR coil must be on outside of cup (but this is actually not new)

# Test Setup

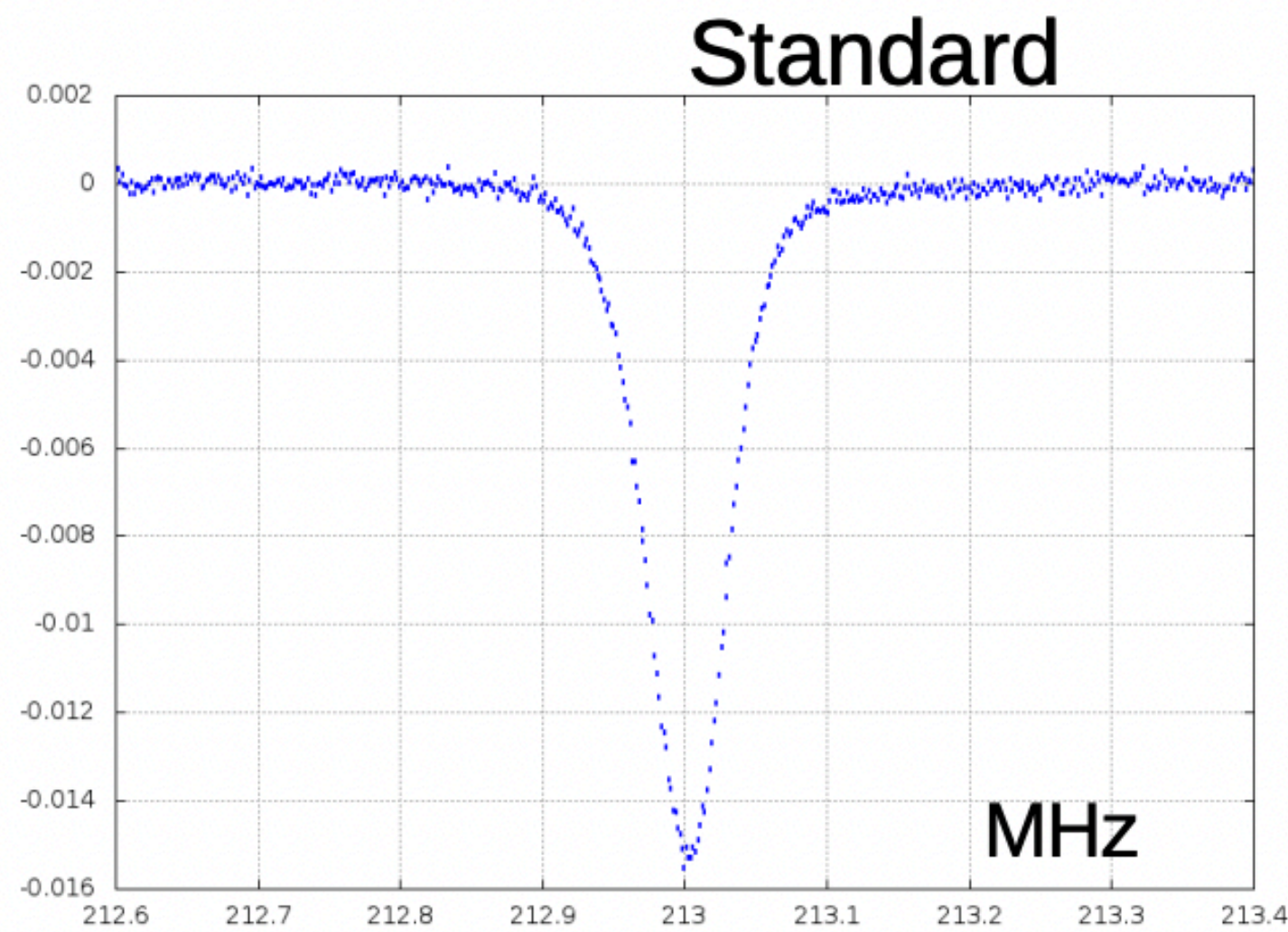


# Small cup test setup

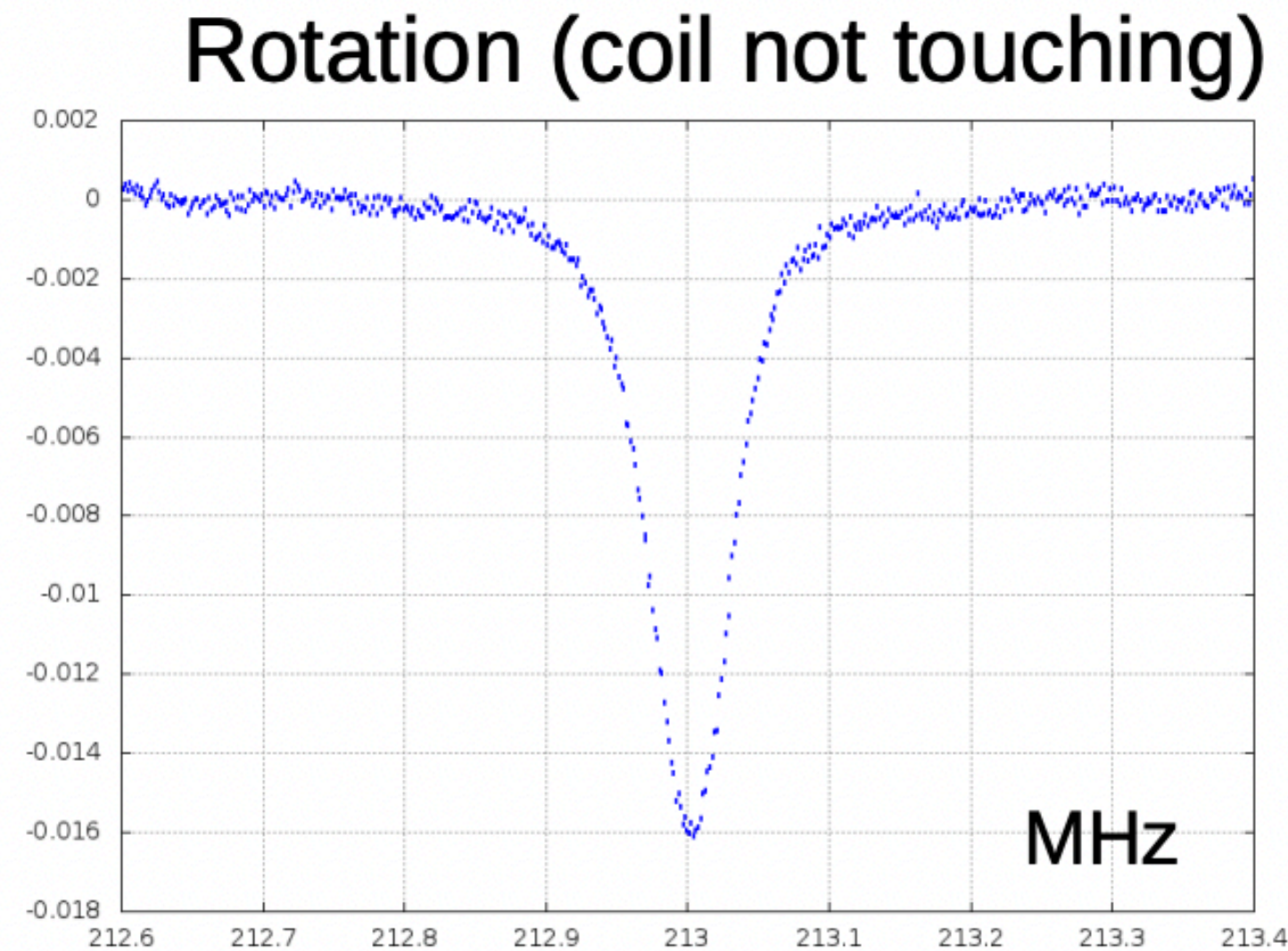


# TE Test Examples

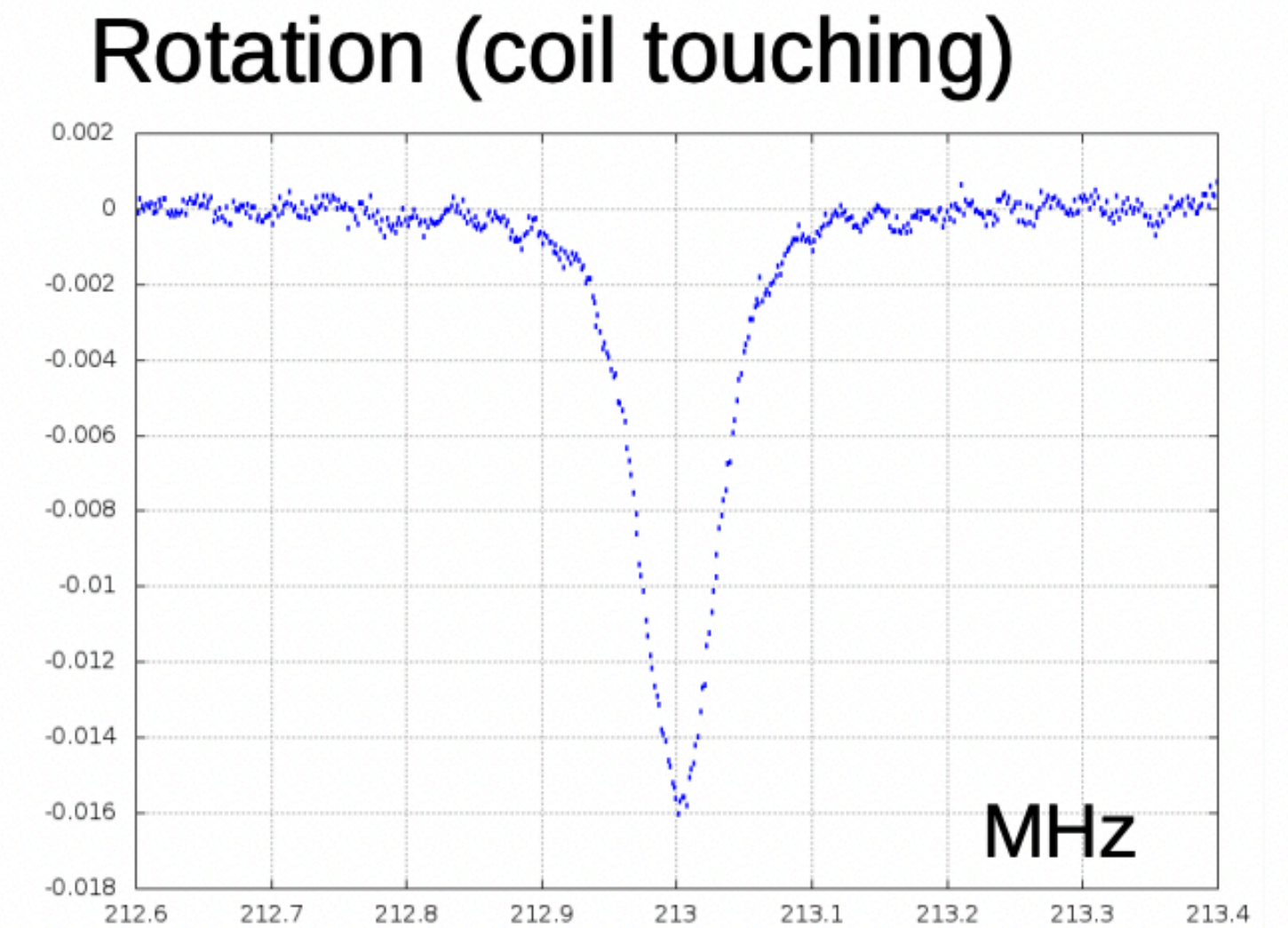
## Testing systematic error level introduced by rotation



Average Area: -0.093471 (0.133%)  
Average Temp: 1.706 K (0.023%)  
TE Polarization: 0.301%  
Calibration Constant: -3.204 (0.135%)

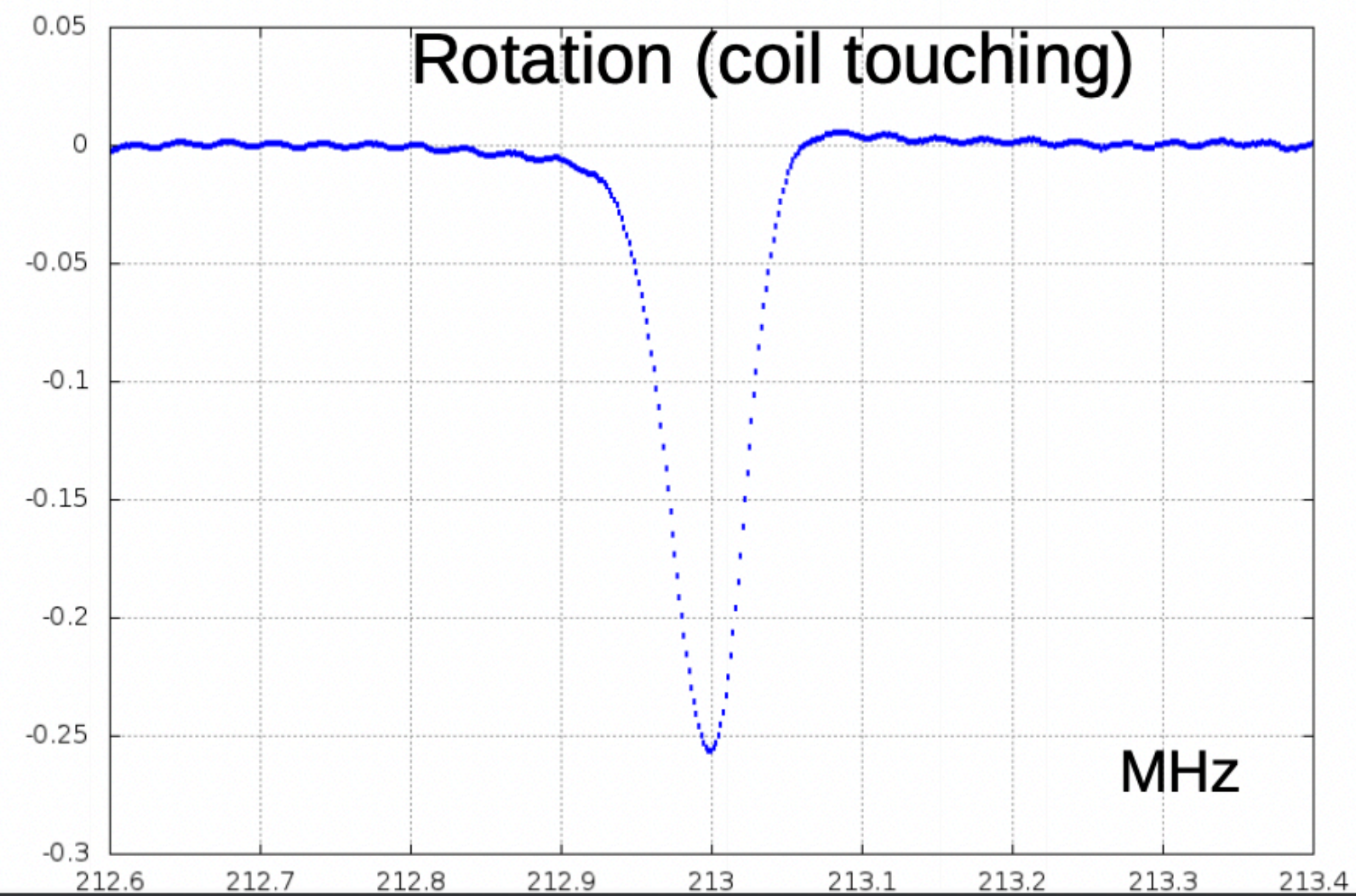
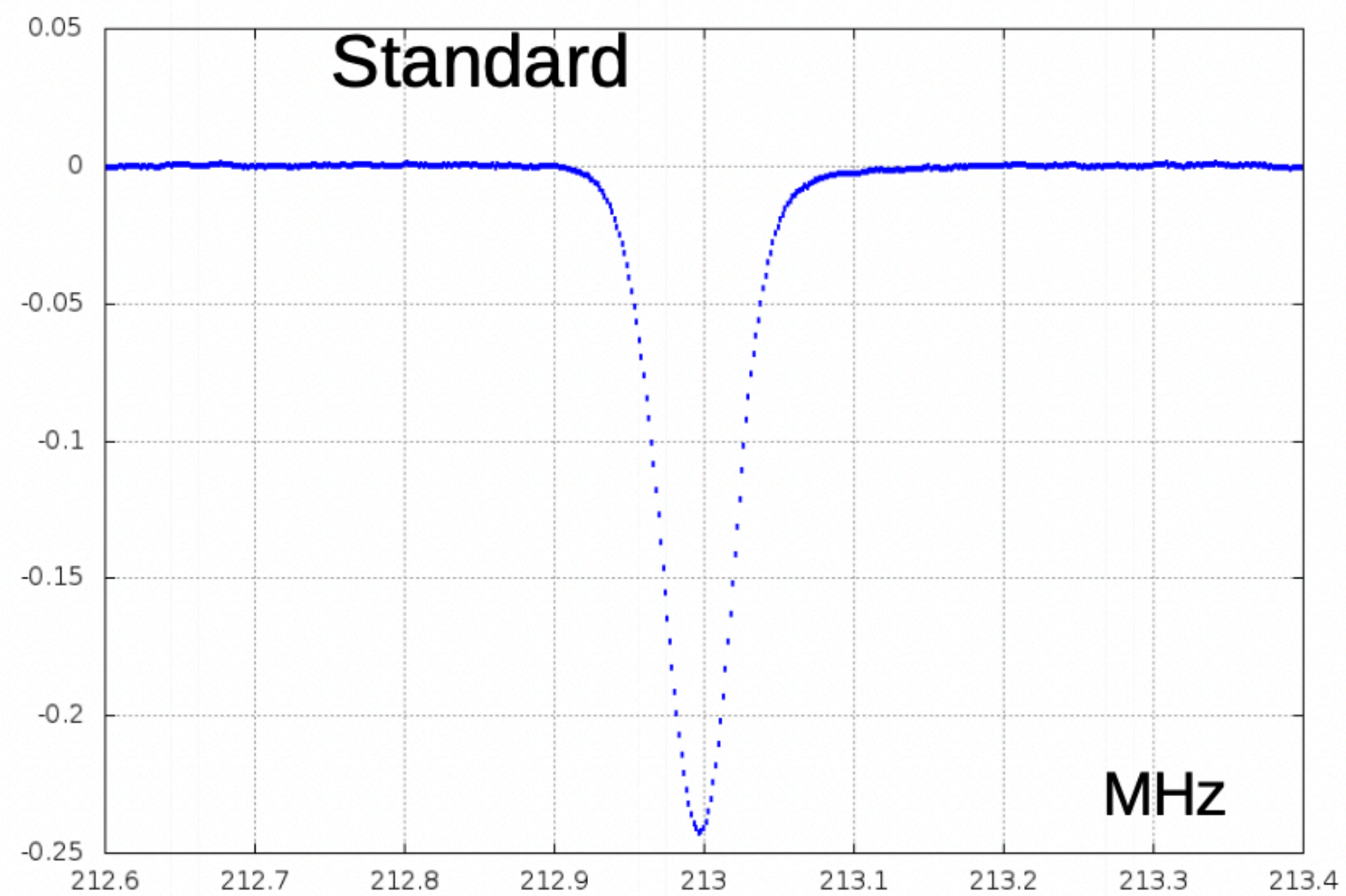
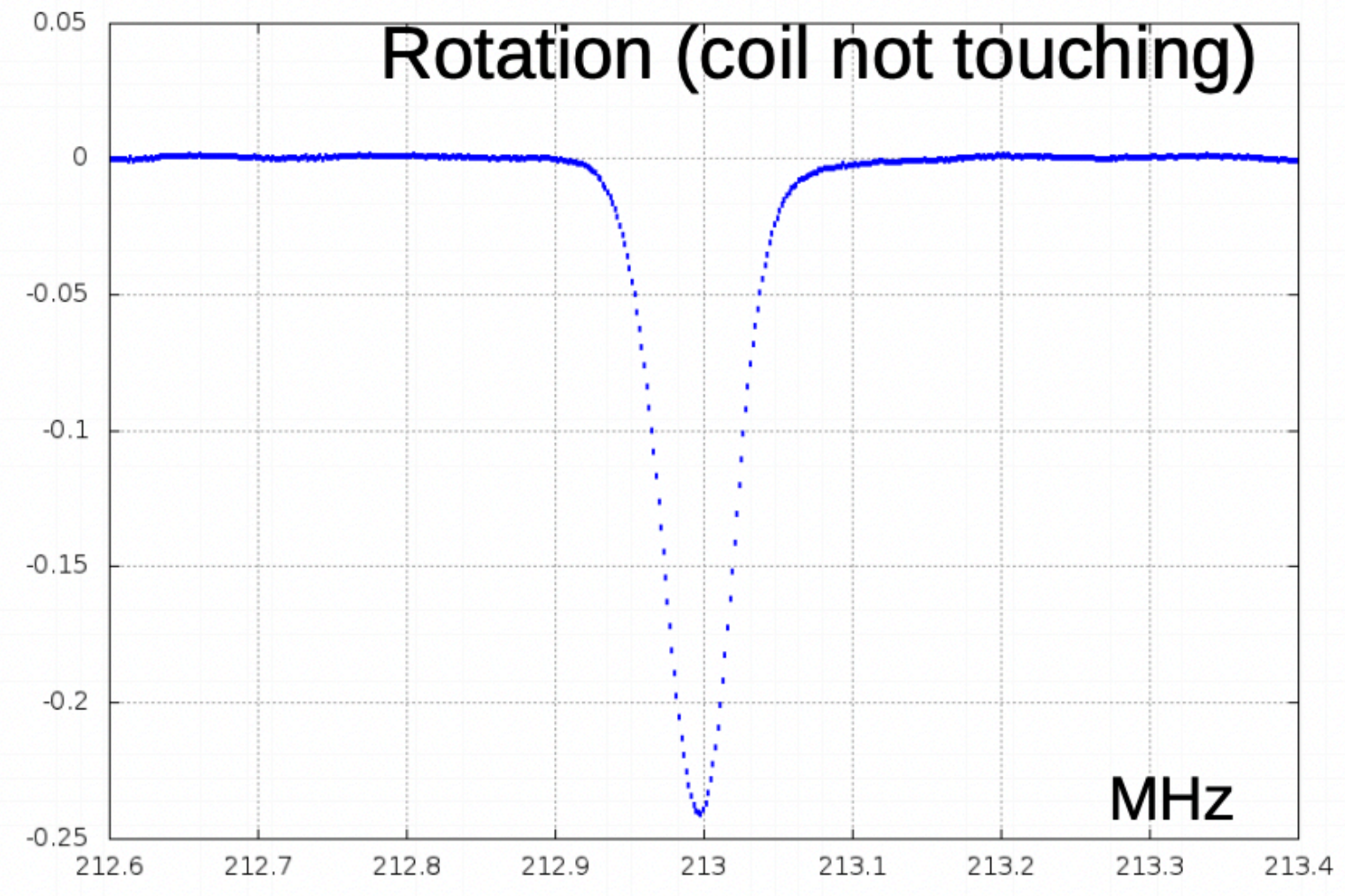
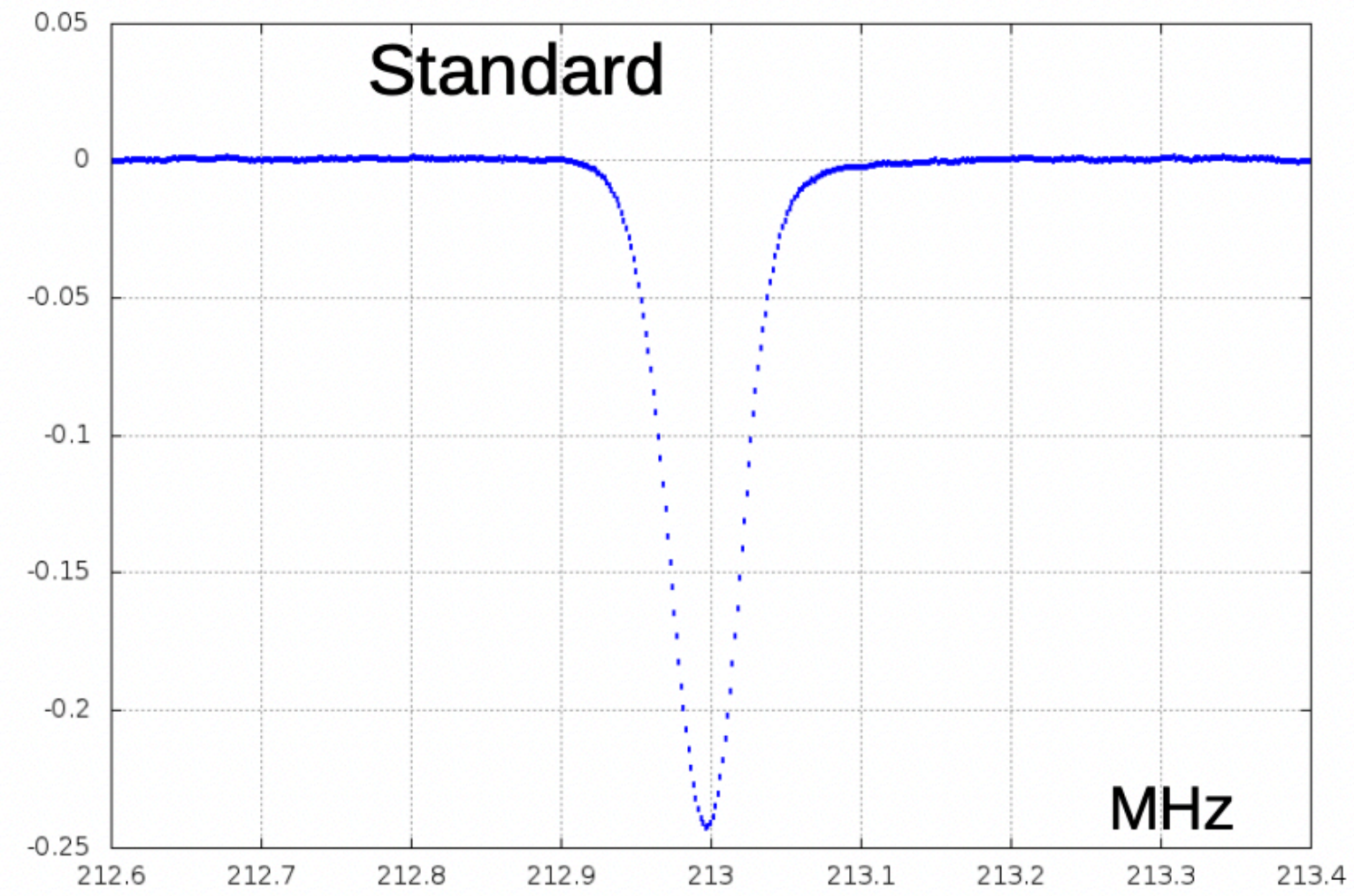


Average Area: -0.086741 (0.167%)  
Average Temp: 1.742 K (0.15%)  
TE Polarization: 0.293%  
Calibration Constant: -3.382 (0.255%)



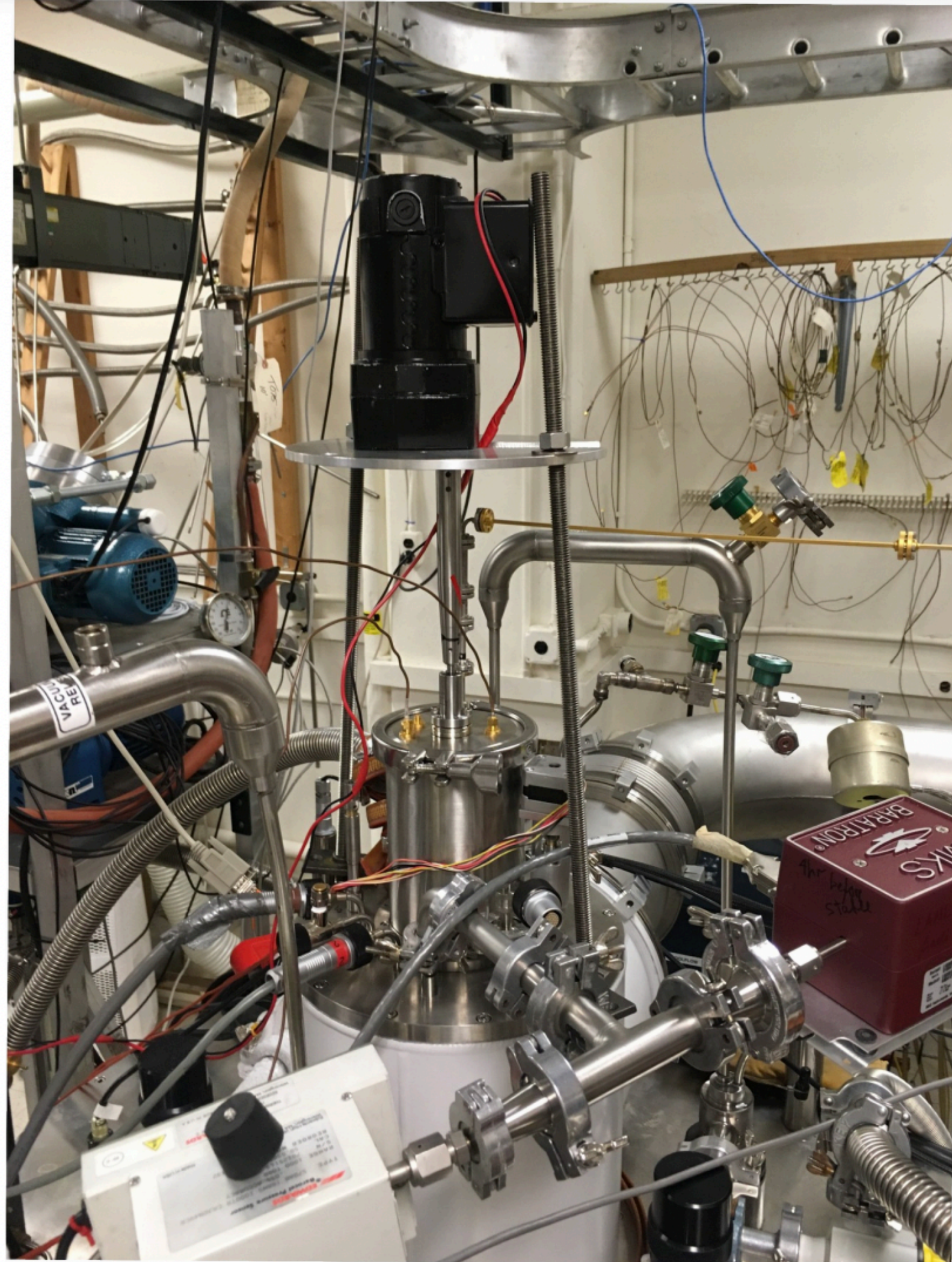
Average Area: -0.08982 (0.277%)  
Average Temp: 1.739 K (0.335%)  
TE Polarization: 0.294%  
Calibration Constant: -3.389 (0.523%)

# Enhanced Signal

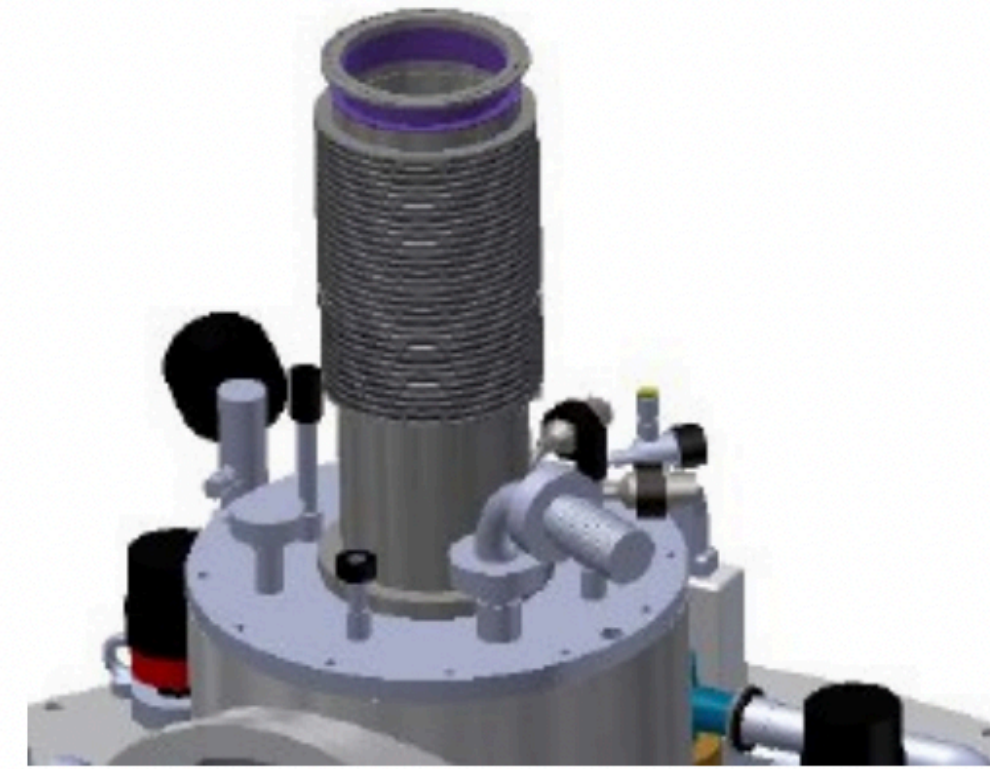




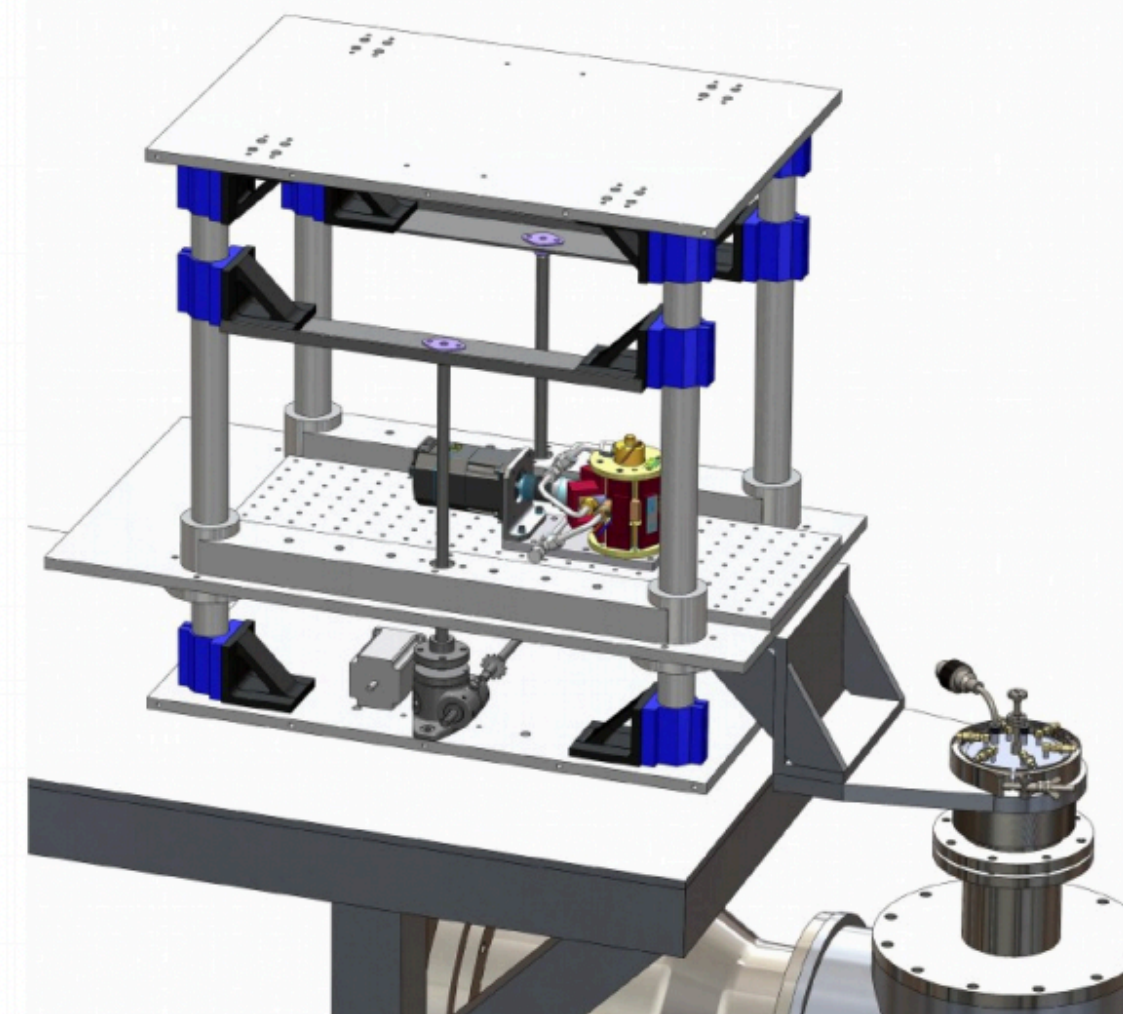
# General Setup Already Tested



Motor Driven Circular Motion



Actuator with Bellows for up and down

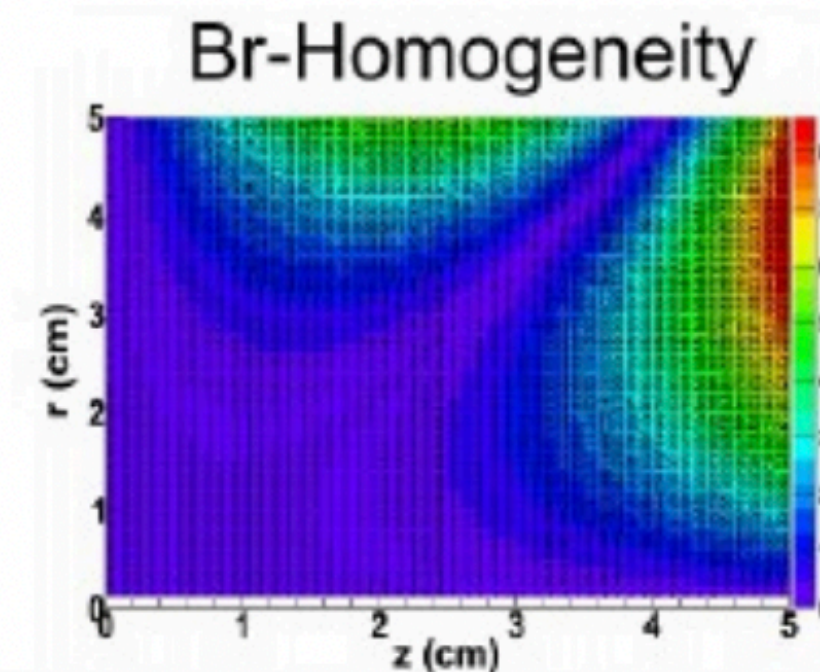
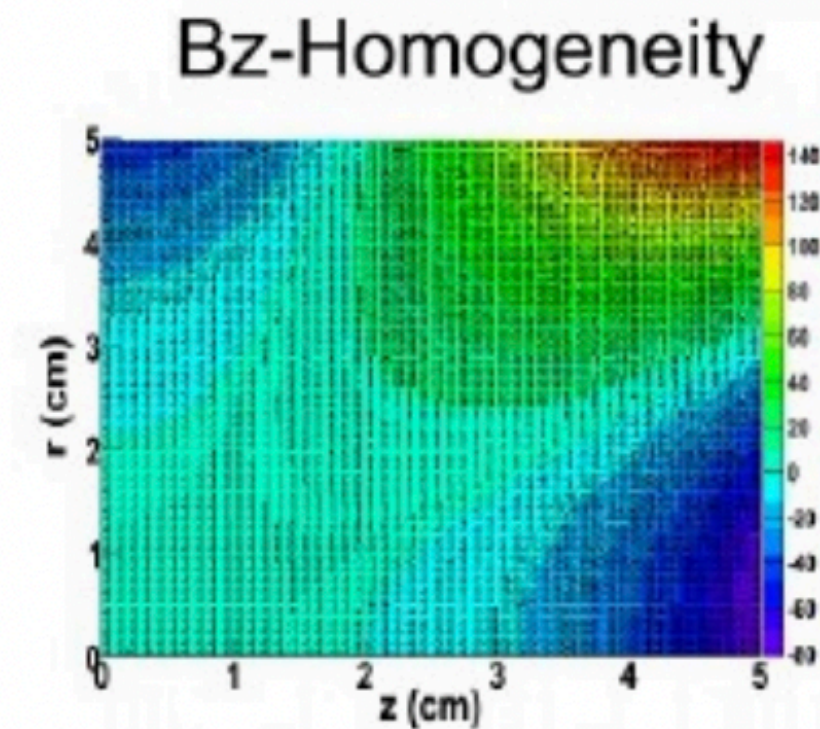
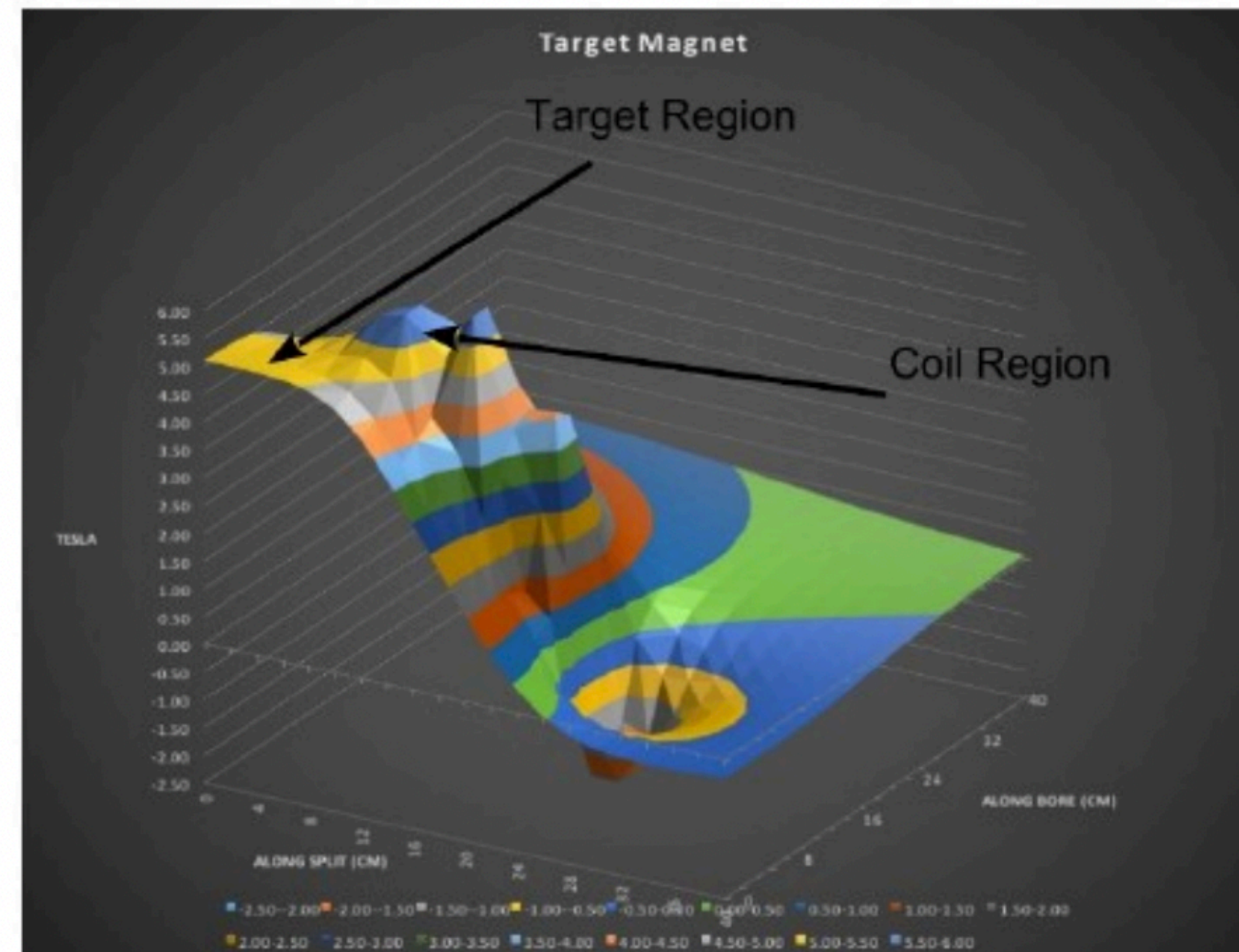


# Details on new magnet needed

- Need new field map
- Geometry
- Field fall off
- Range of homogeneity

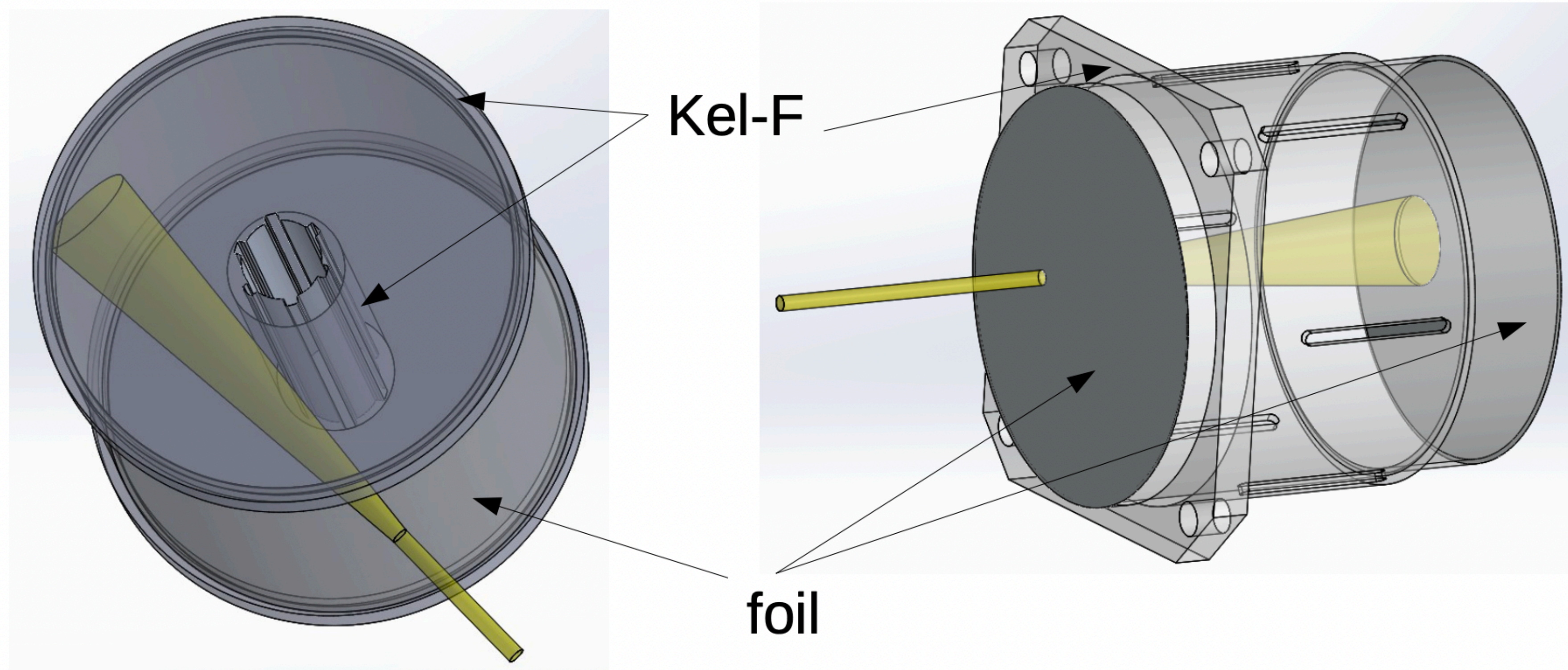
- Rotation rate  $\omega_f > f_0 (B_r) t_1$
- Field region would allow larger cups up to 5 cm diameter
- Size of cup ultimately limited by fridge
- Position NMR loop on the side of the field

Expand size of cup outside of homogeneity

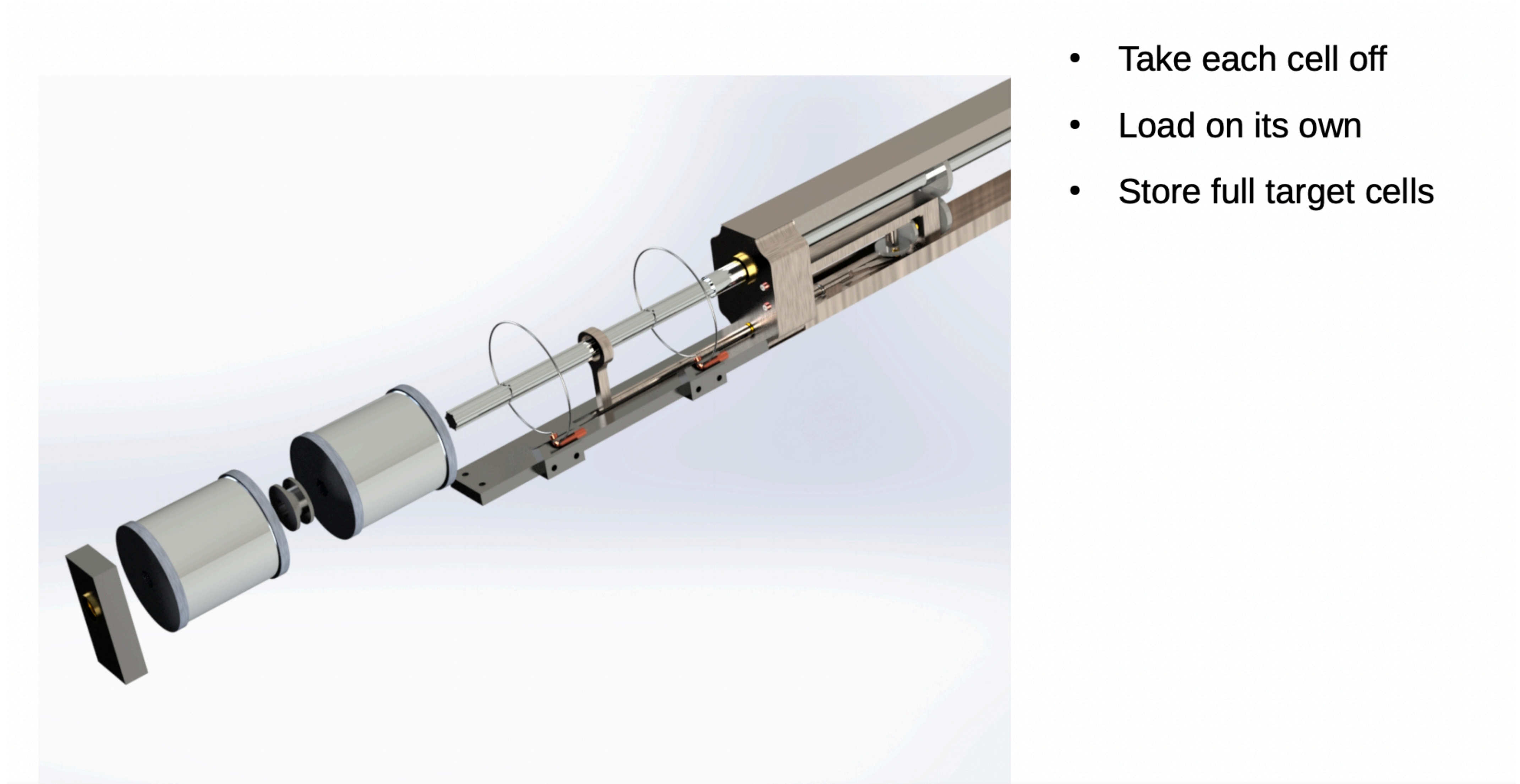


# Cup and insert Variations

## Exploring Alternative Design



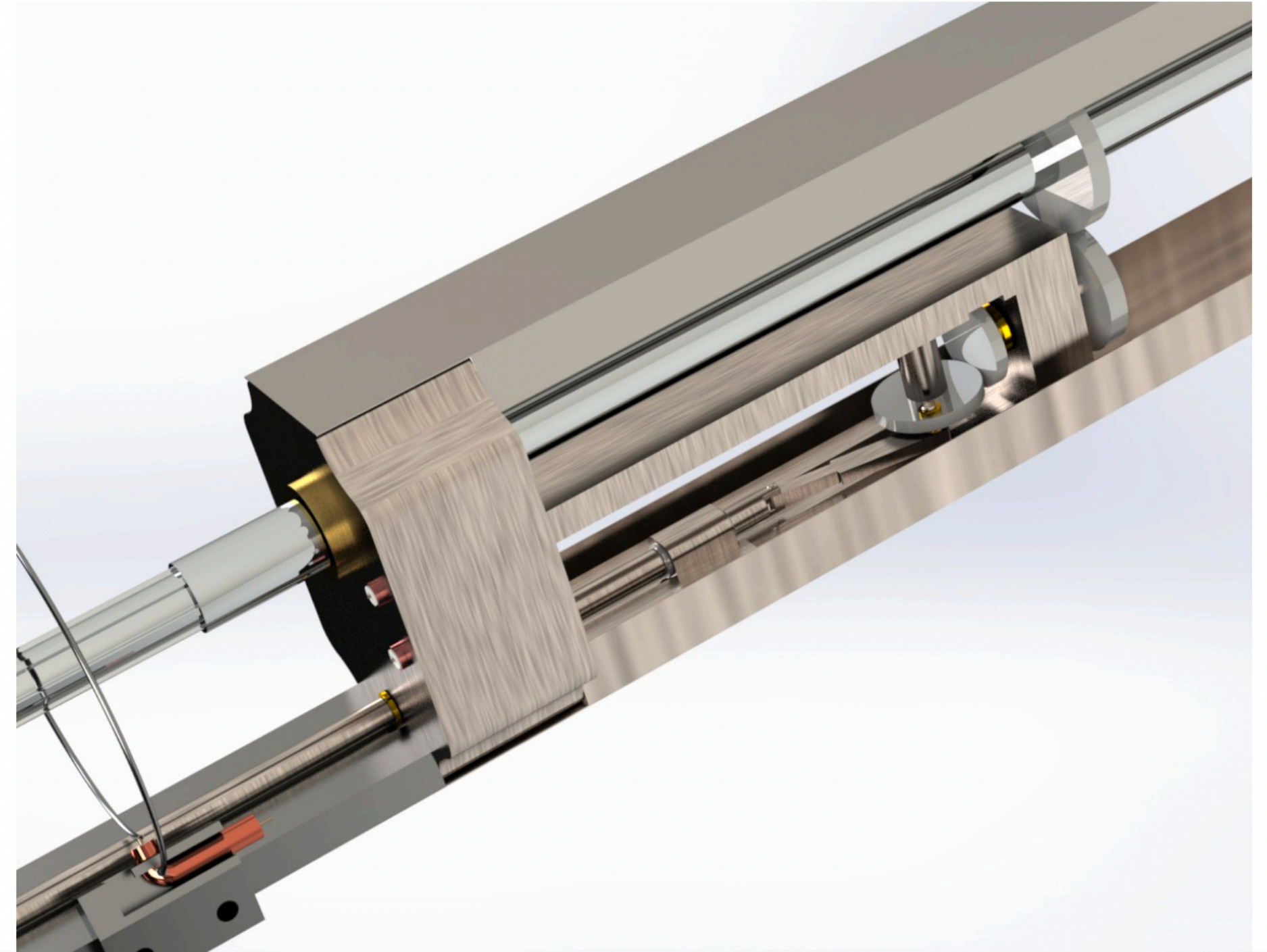
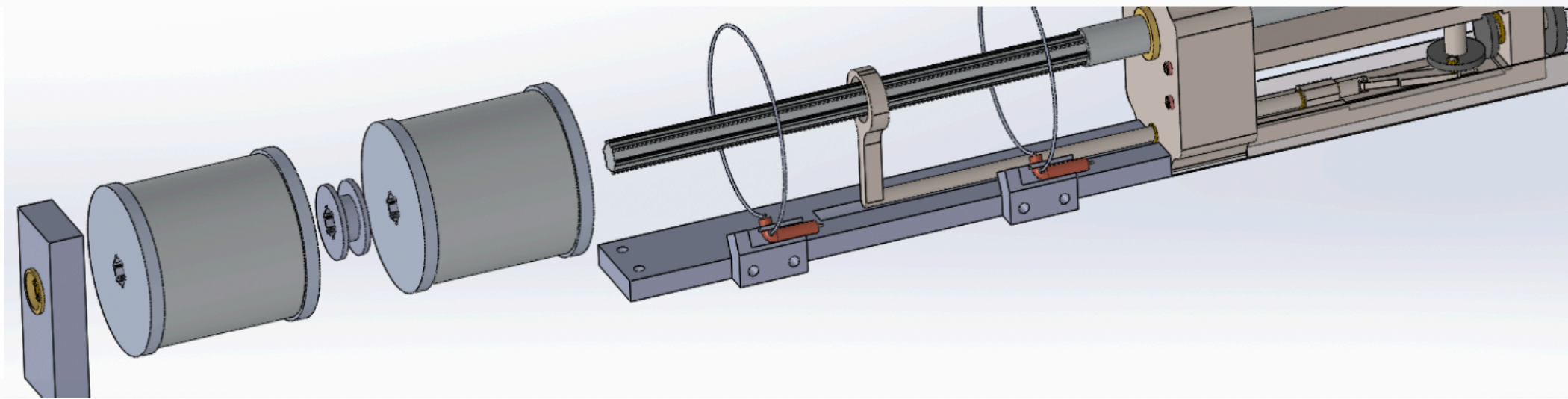
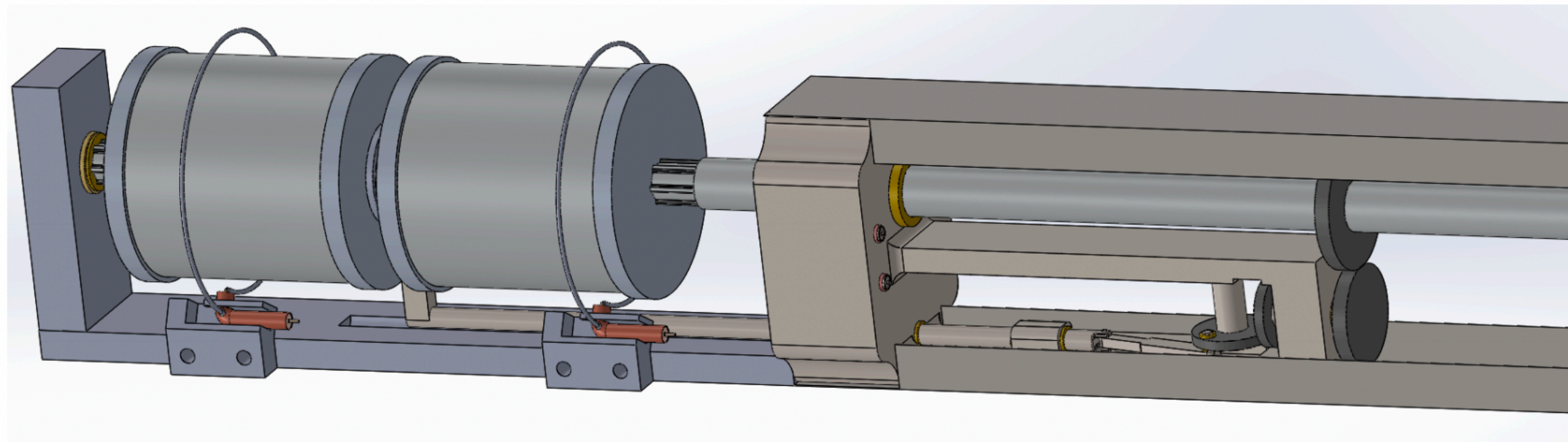
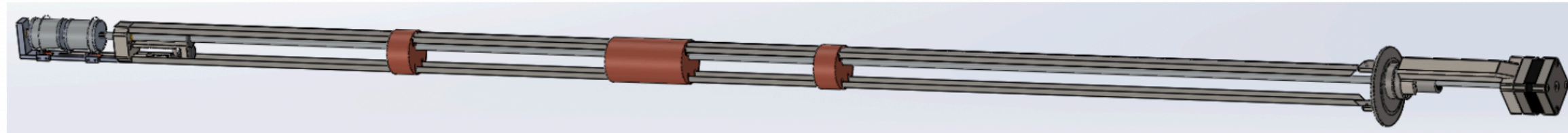
# One of many possibilities to optimize



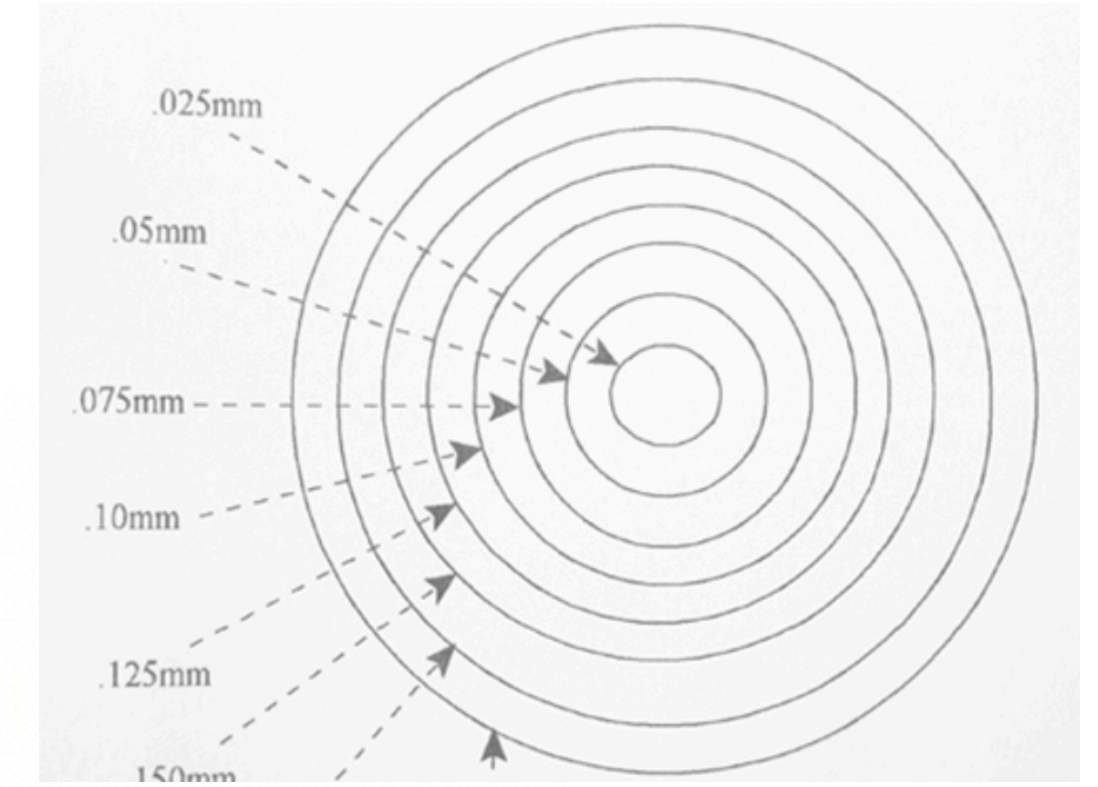
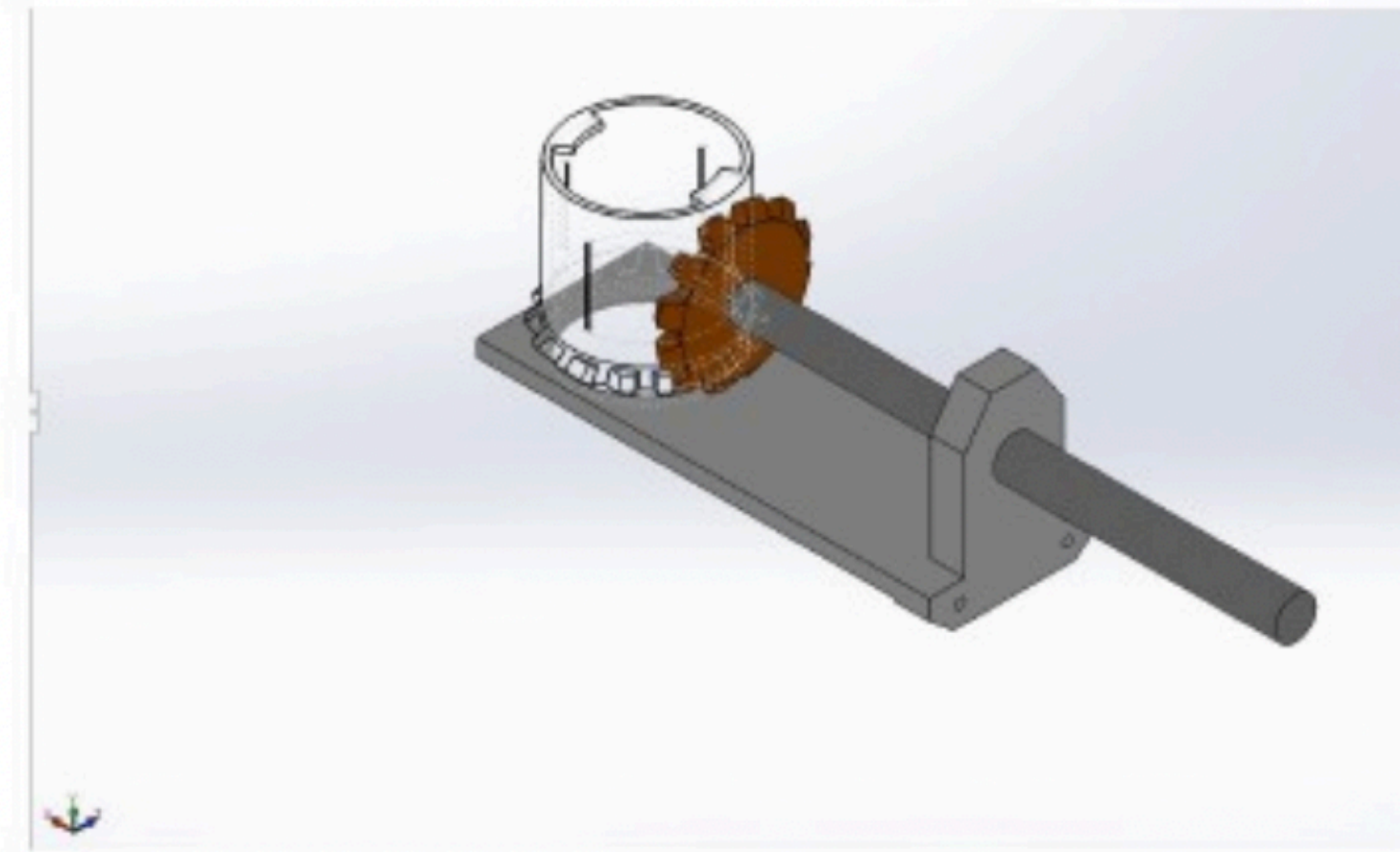
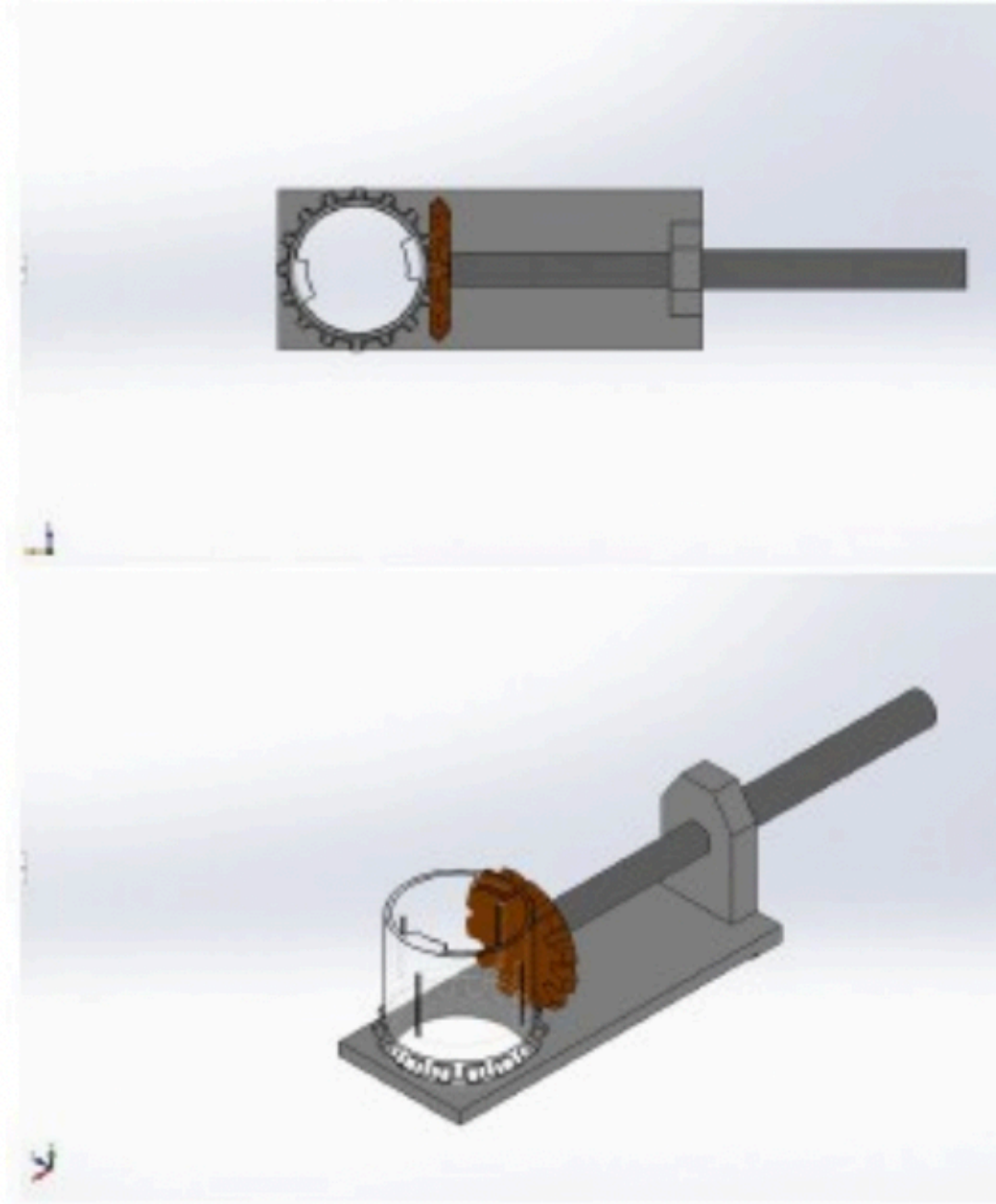
- Take each cell off
- Load on its own
- Store full target cells

# Alternative Insert

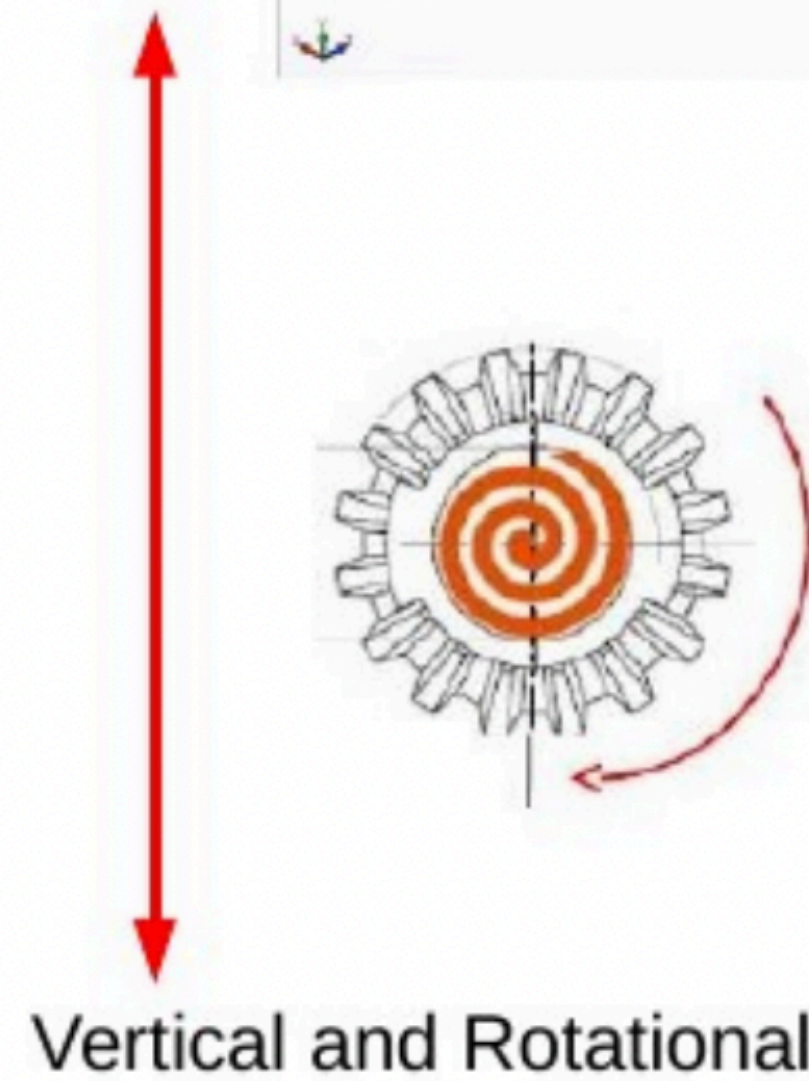
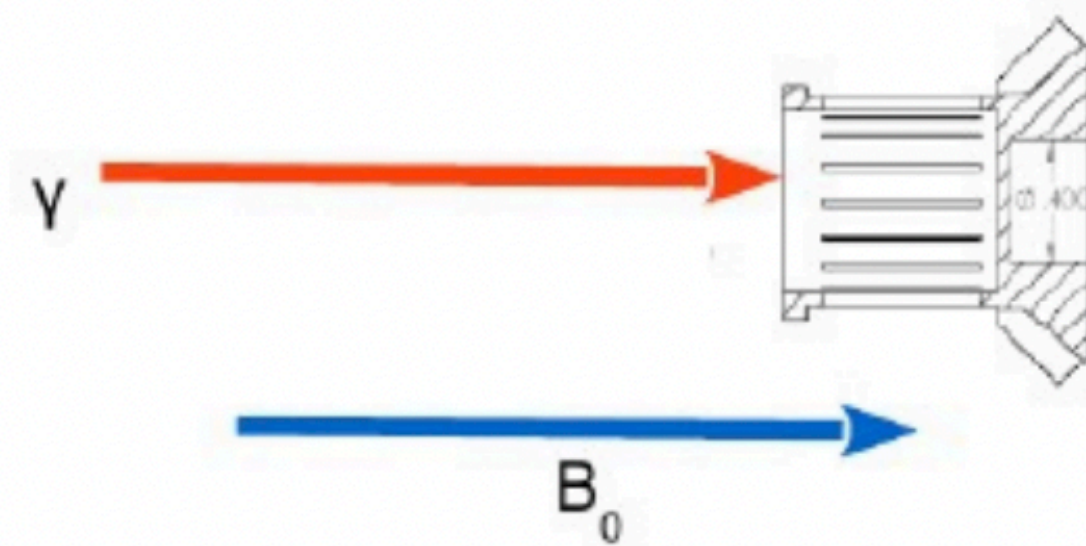
Optimized for maintenance, target volume, rotation speed, up-down motion



# Simple Prototype



- Use concentric circles
- Multiple rotation per position
- Minimize up and down motion
- Control rotation rate based on position



Vertical and Rotational

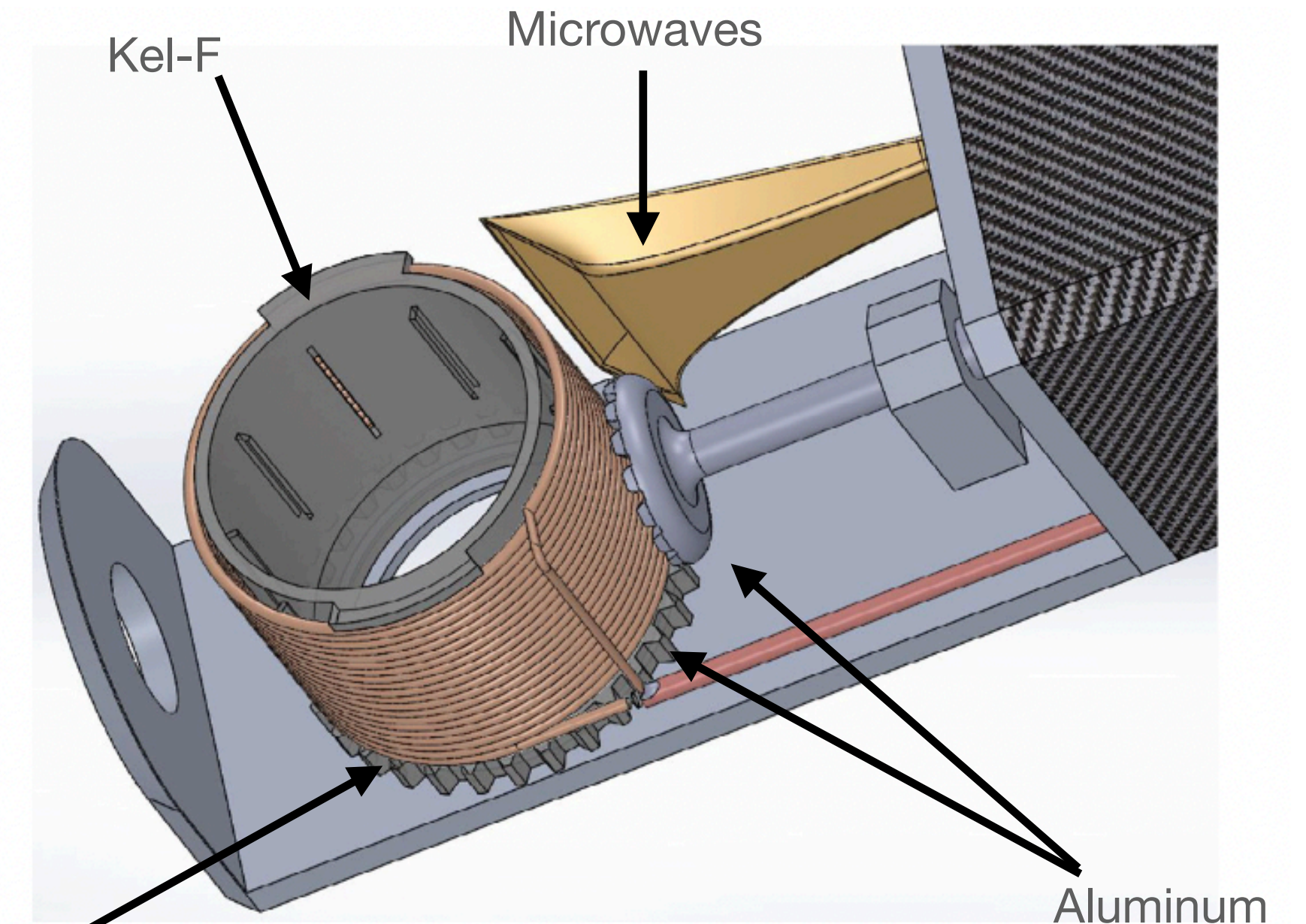
- Control target position
- Rotate while moving up and down
- Similar to standard dimensions  
3 cm x 2.7 cm
- Also possible to expand dimensions
- Keep rotation cycles consistent per physics run for systematic regularity

# Standard Design

Design as close to previously used insert as possible

- Moves up and down (+/-10 mm)
- Rotates ~1 Hz
- Every about the drive gear is Al and Kel-F
- NMR outside cup

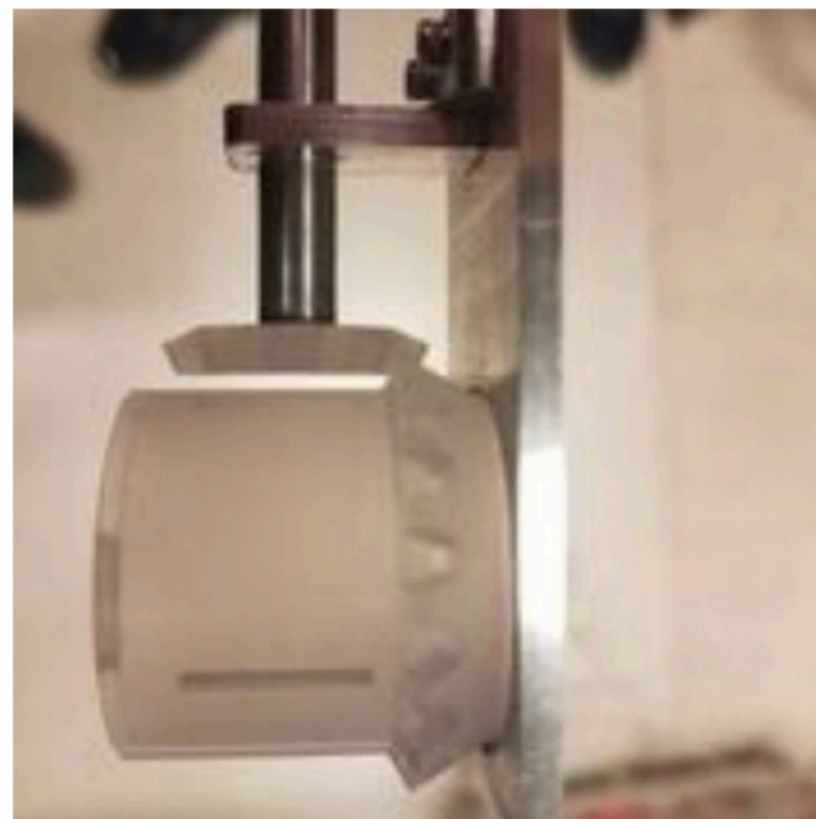
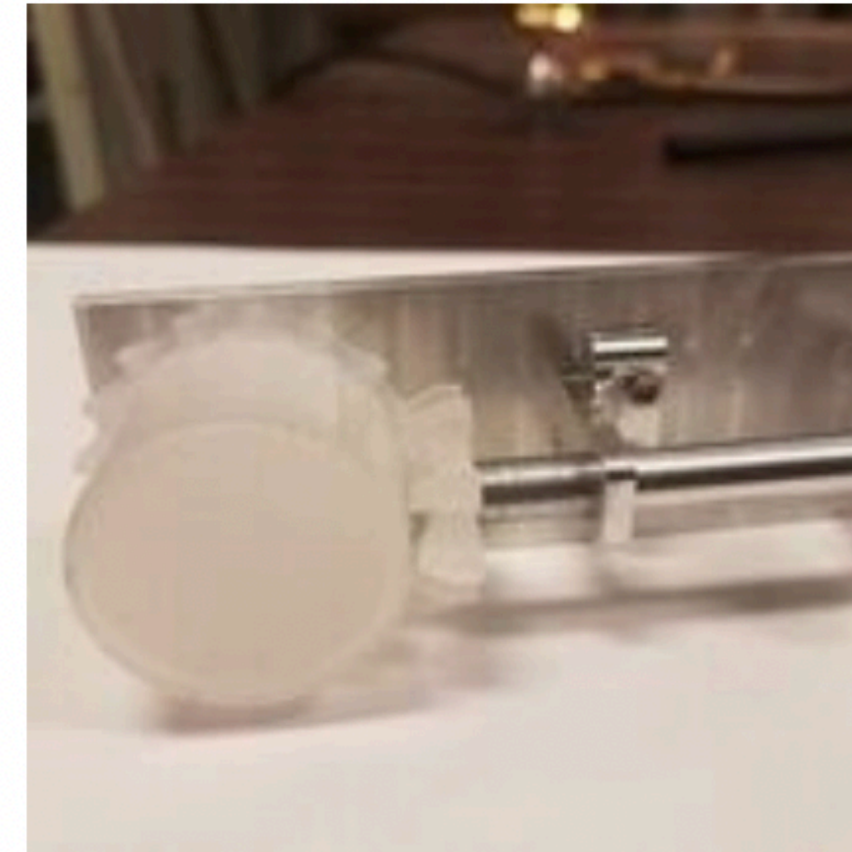
Polychlorotrifluoroethylene



*Nuclear Inst. and Methods in Physics Research, A 981 (2020) 164504*

Pressed fit bearing

# Simplest Design for CPS insert





# Present Status

## And for a while...

- Heat-load Estimates worked out (total and surface effects)
- Rotation Speed Estimate worked out
- General design worked out
- Prototyping complete with real cooldown testing
- No additional research on insert model optimization (go with close to standard?)
- No heat-load to rotation rate studies
  - Much more sophisticated MC (\$)
  - Additional cooldowns for long running rotation/up-down (\$\$)
  - Prototyping in beam at NIST (\$\$\$)

# What makes sense to do in the near term

## On a budget

- Make the final insert for the fridge-magnet that will be used
  - probably only one for now

# What makes sense to do in the far term

## Closer to run time

- Develop the software to match the insert and rotation scheme
- Have intelligent controls system for rotation and up and down motion driven by stepper motor and actuator
- Have intelligent monitor that tabulates radiation dose over volume and does differential polarization estimate/measurements