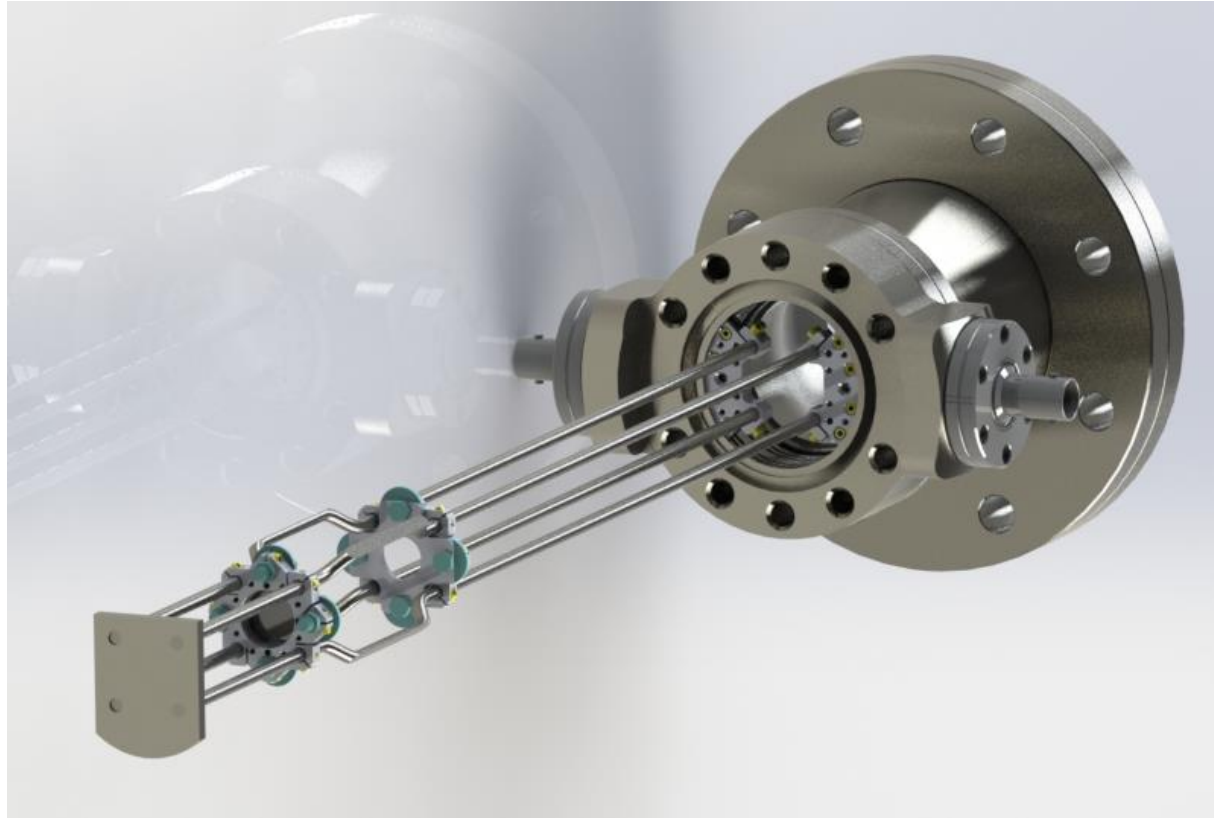


# Pulse-Field Ionization Spectrometer for Rydberg Impurity Detection in Bose-Einstein Condensates



Chase Heinen

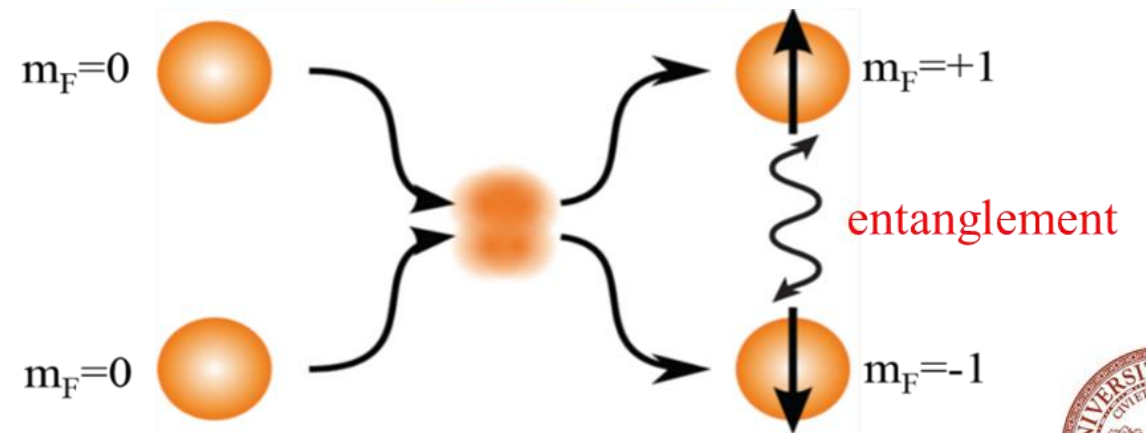
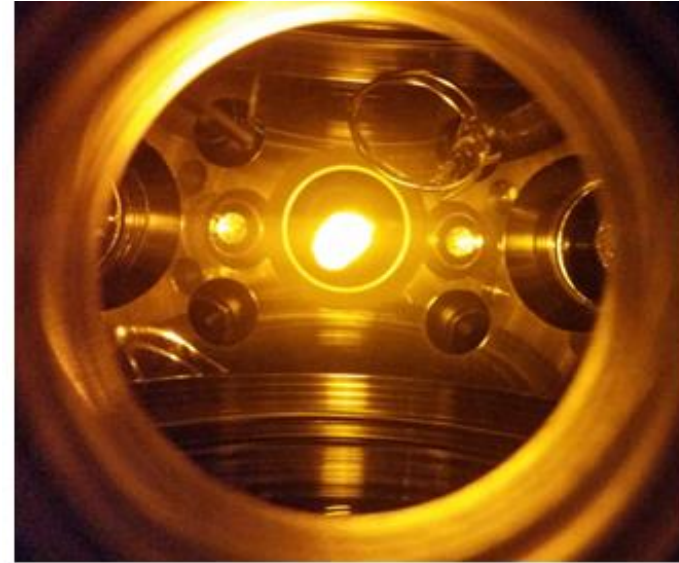
Advisor: Dr. Arne Schwettmann

2020 REU Summer Project



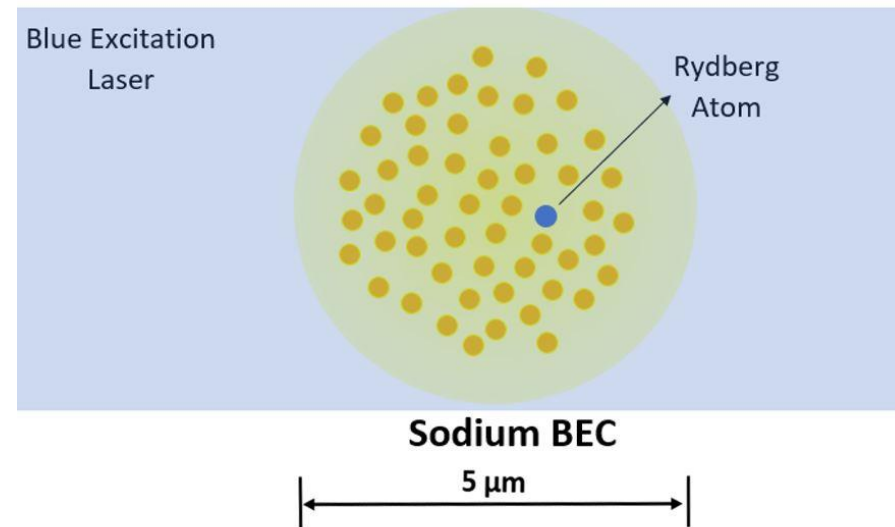
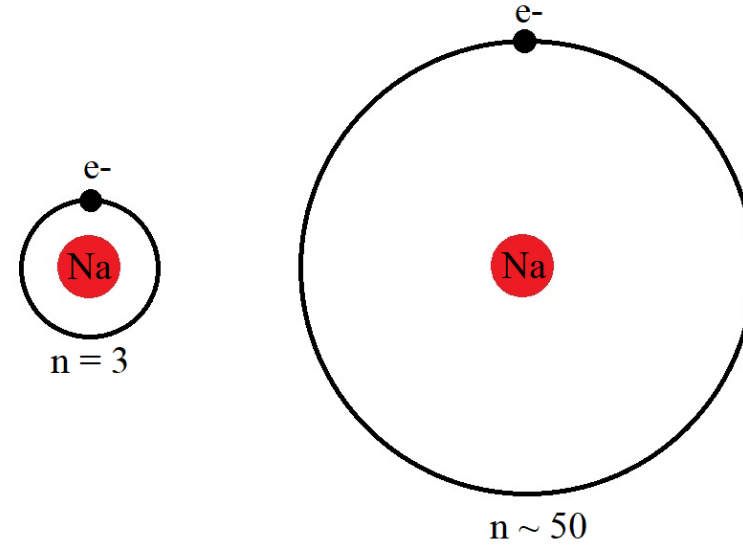
# Bose-Einstein Condensates

- Ultra cold sodium gas
- 100 nK
- State of matter
- Single quantum object
- Spin exchange collisions create entanglement
- Quantum enhanced sensing



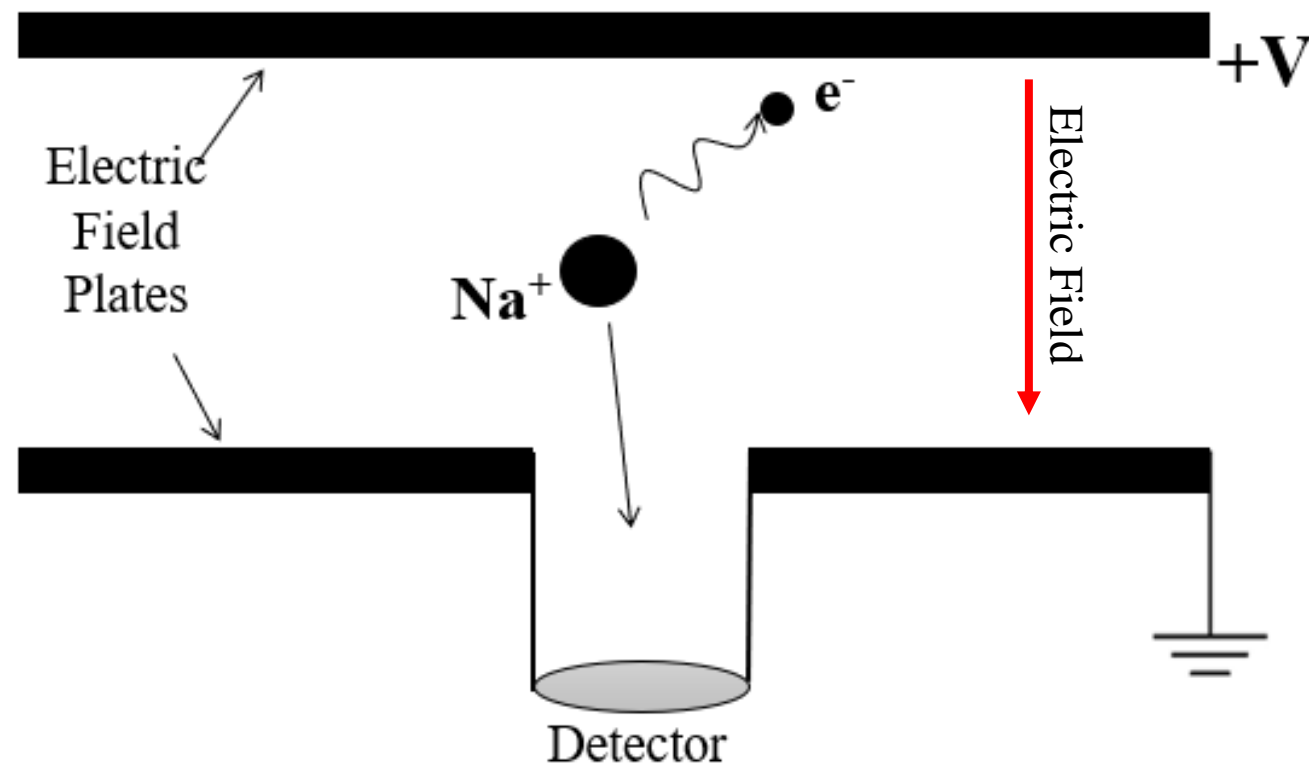
# Studying Impurities

- What is the role of impurities?
- Controlling impurity excitation
- Rydberg atoms
- Electric dipole
- Better understand role of impurities

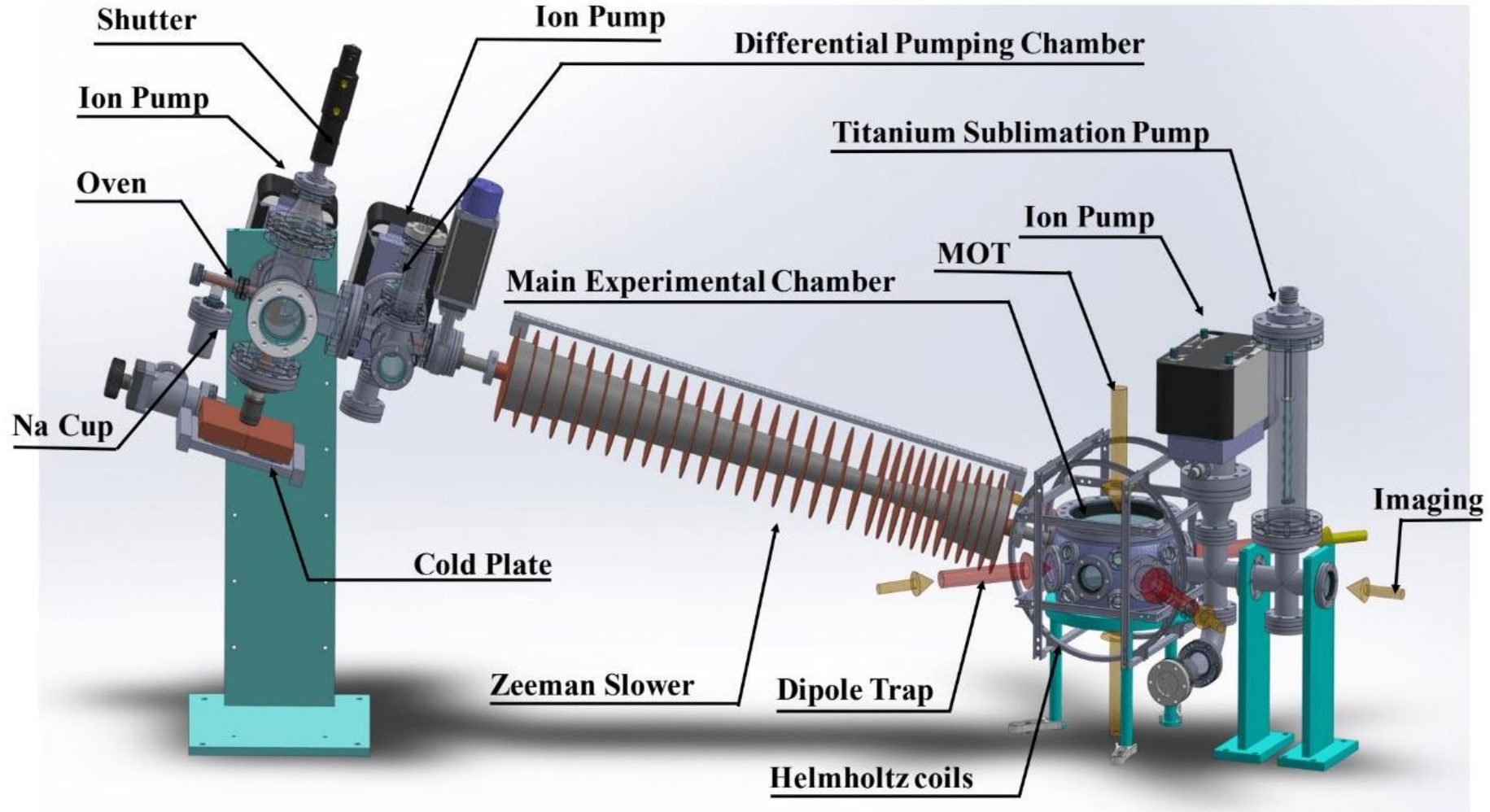


# Pulse-Field Ionization Spectrometer

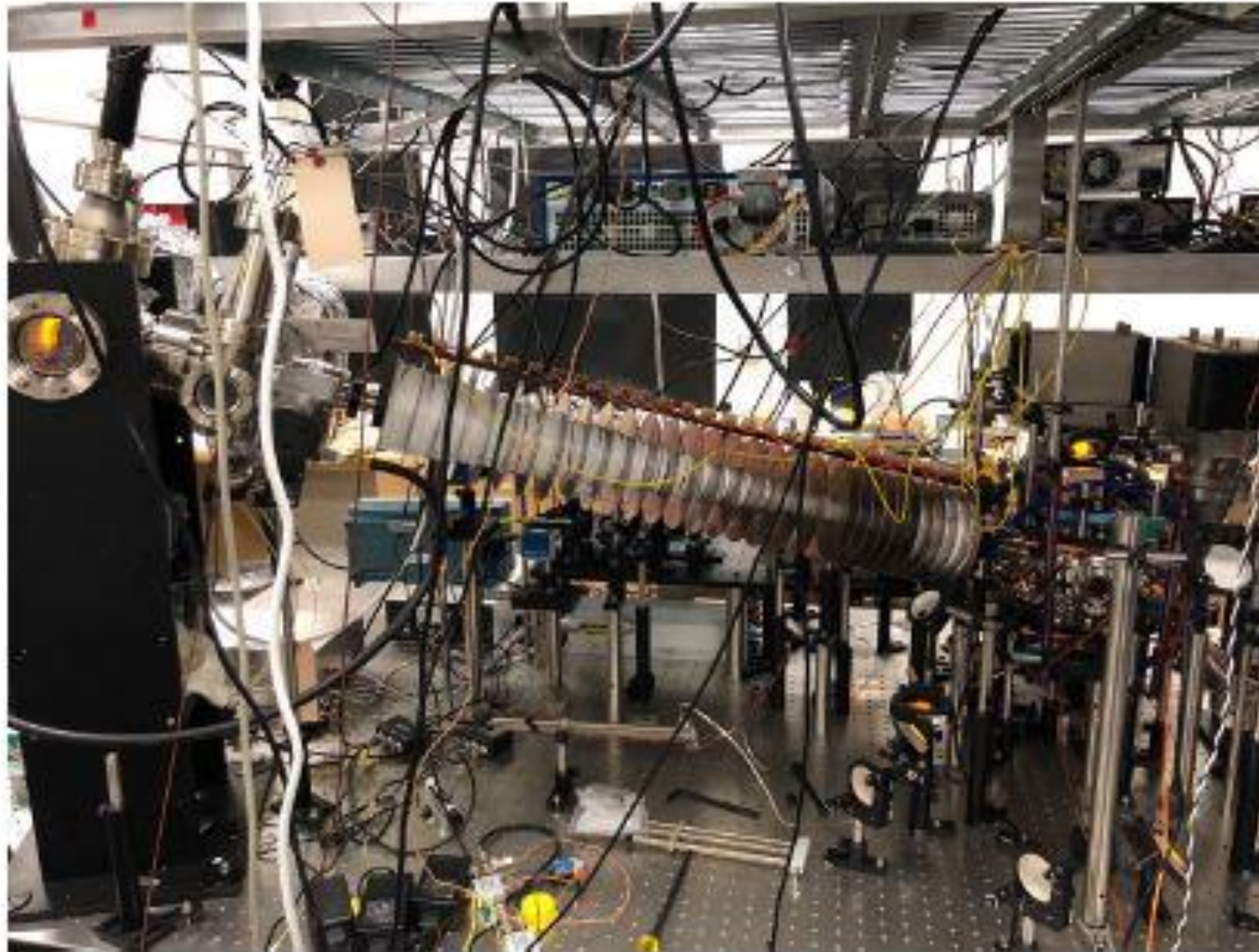
- Need to detect Rydberg impurities
- Ionize atom with electrically charged plates
- Accelerate ion towards detector



# Creating BECs at OU

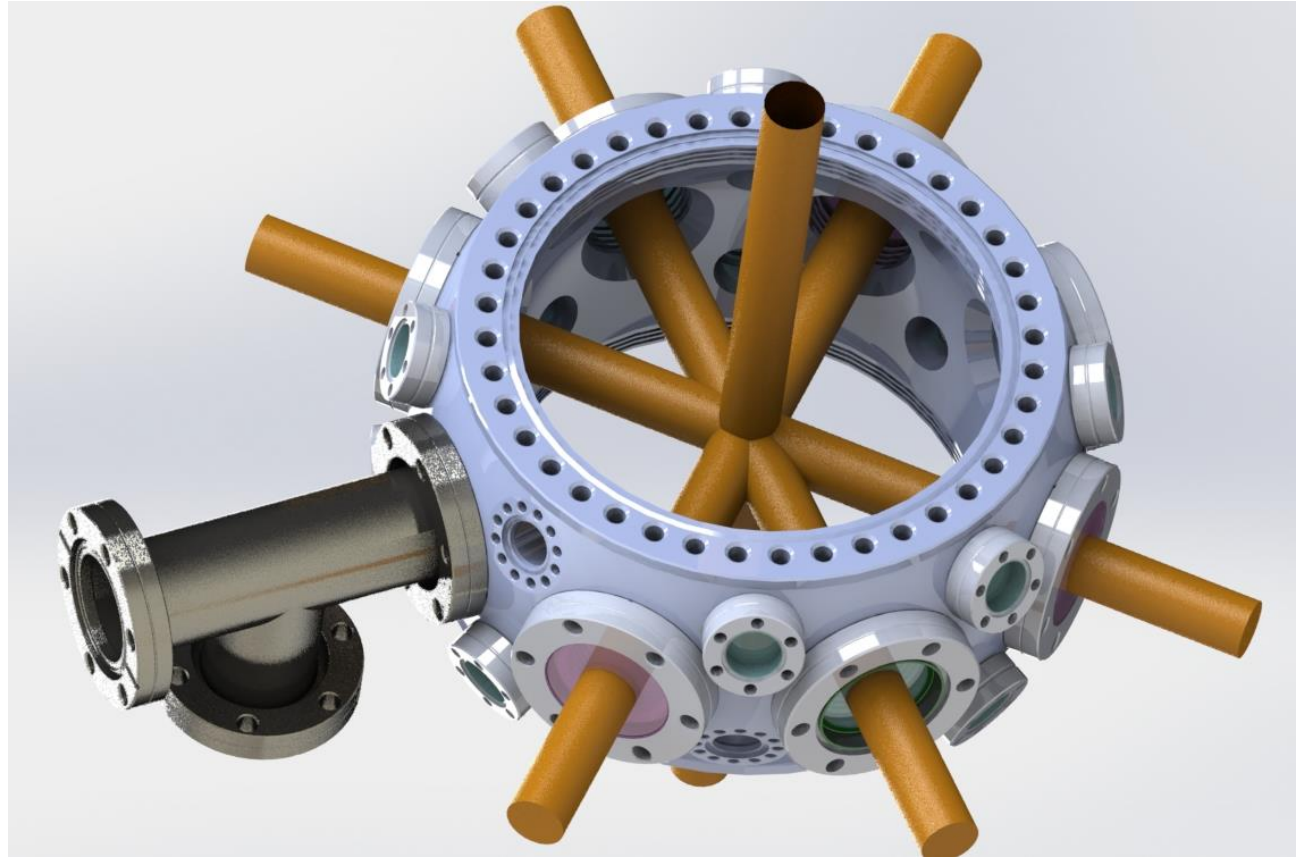


# Creating BECs at OU



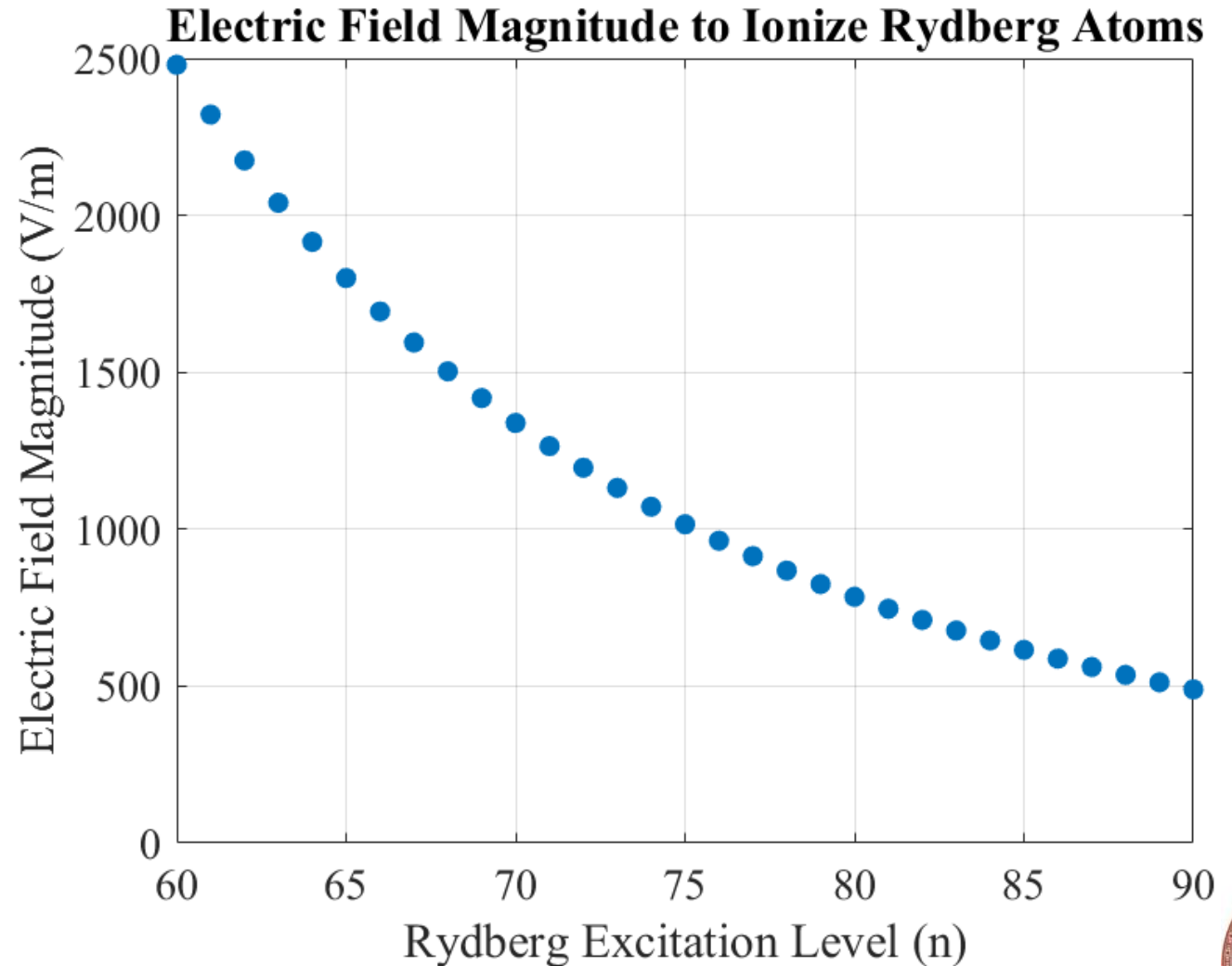
# Design Constraints

- Cannot block lasers
- Cannot deconstruct chamber
- Slide into existing tee pipe



# Design Constraints

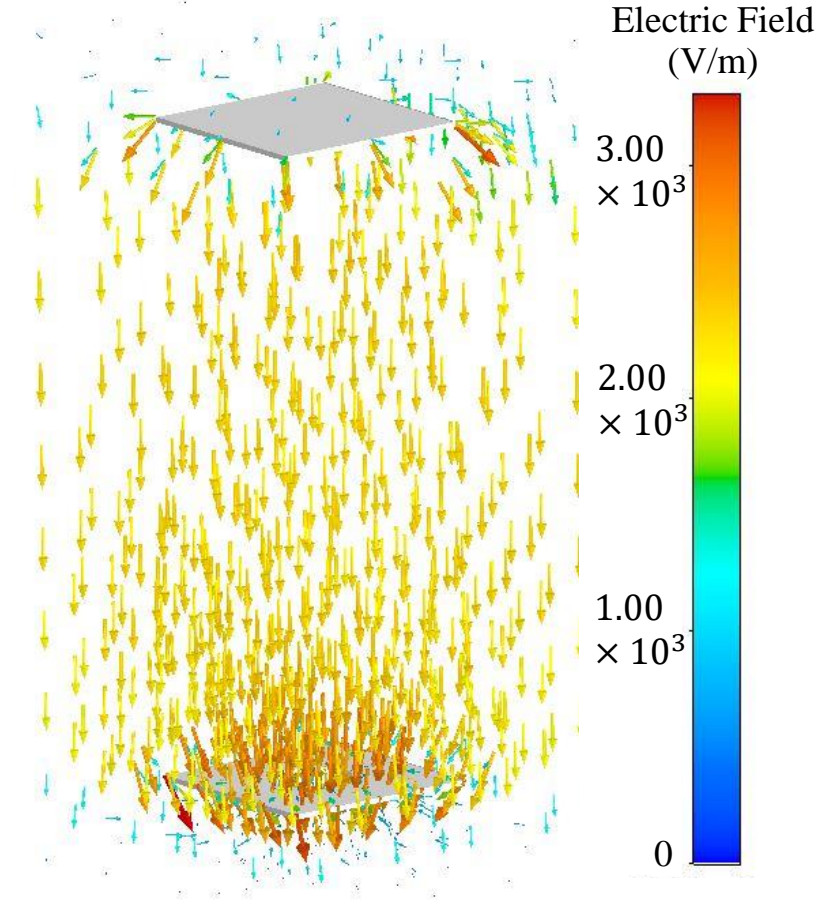
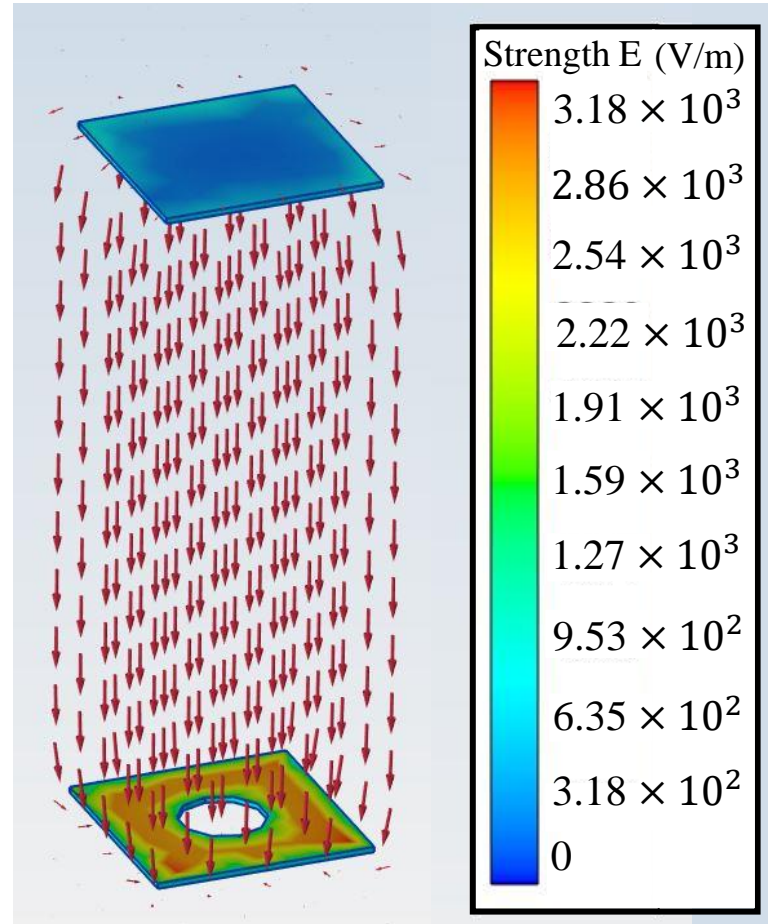
- Can create Rydberg atoms from  $n=60$  to  $n=90$
- Need large enough electric field for ionization





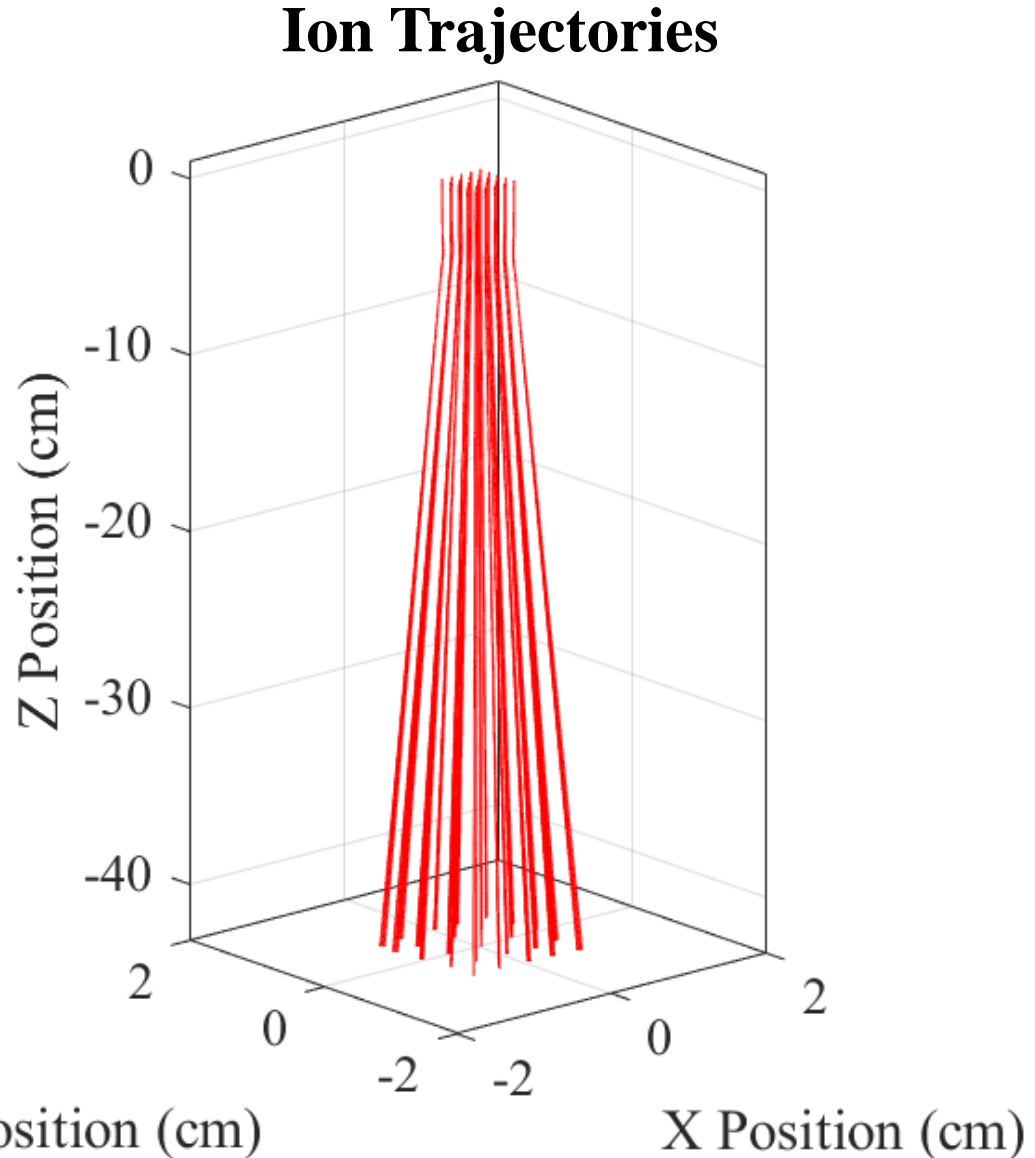
# Calculating Electric Field Values in 3D

- ANSYS Discovery AIM Student
- Simulate electric fields from plate configurations
- Export field data



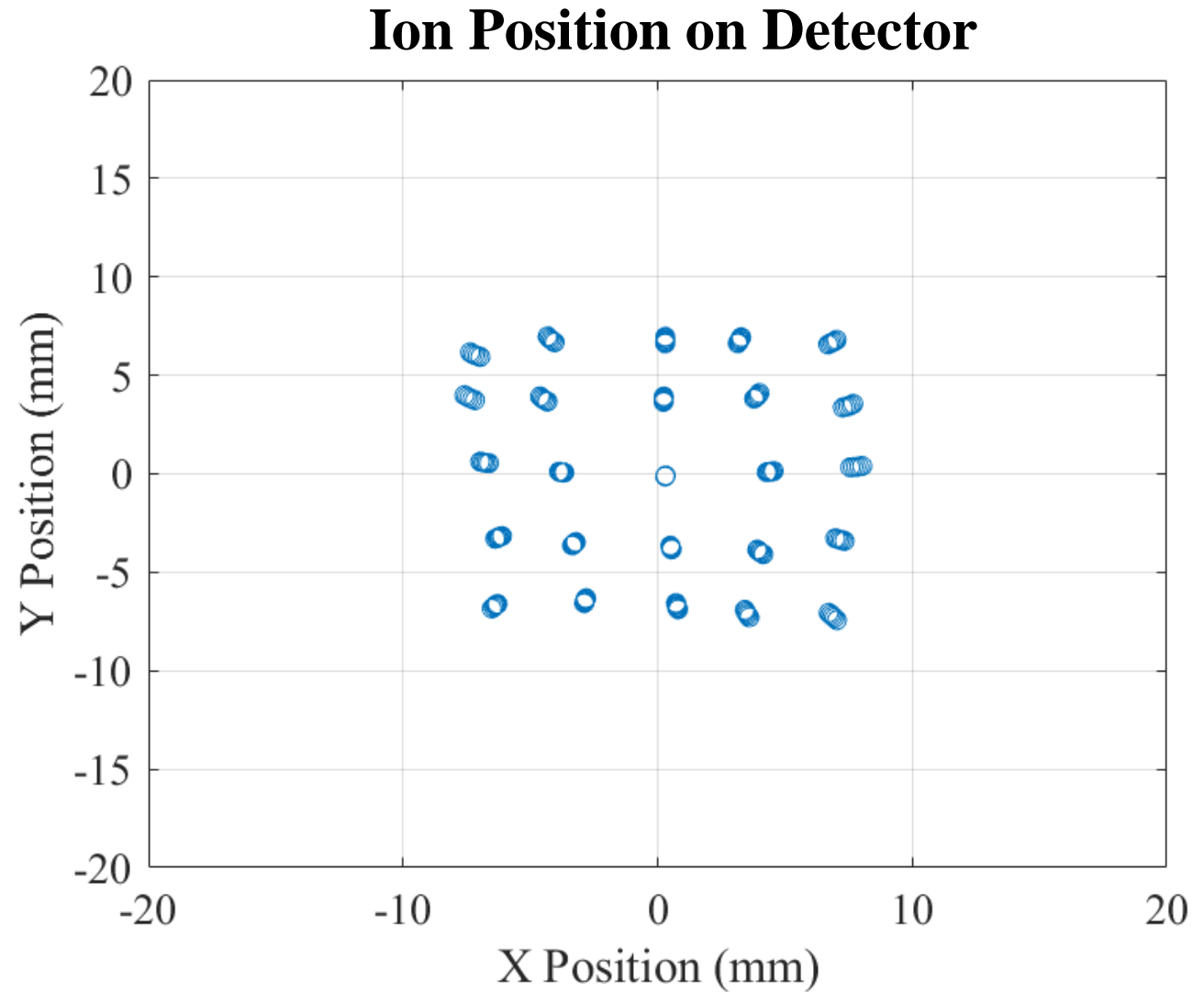
# Simulating Ion Trajectory

- Simulate motion of atoms
- 125 starting positions
- 1 ns time steps
- Calculate acceleration, velocity, and position
- Lensing from hole can be seen



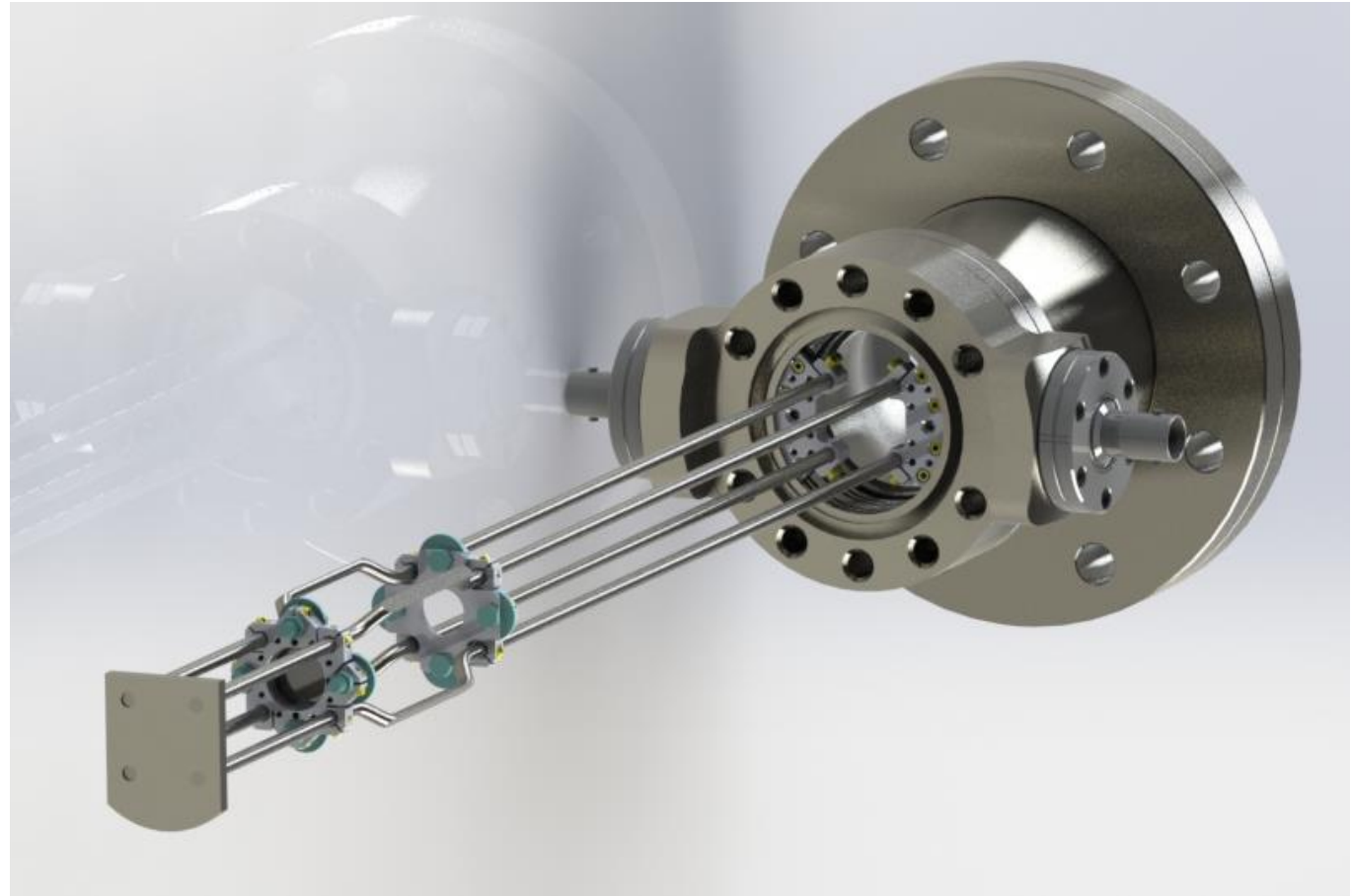
# Simulating Ion Trajectory

- Ensure that all ions are detected

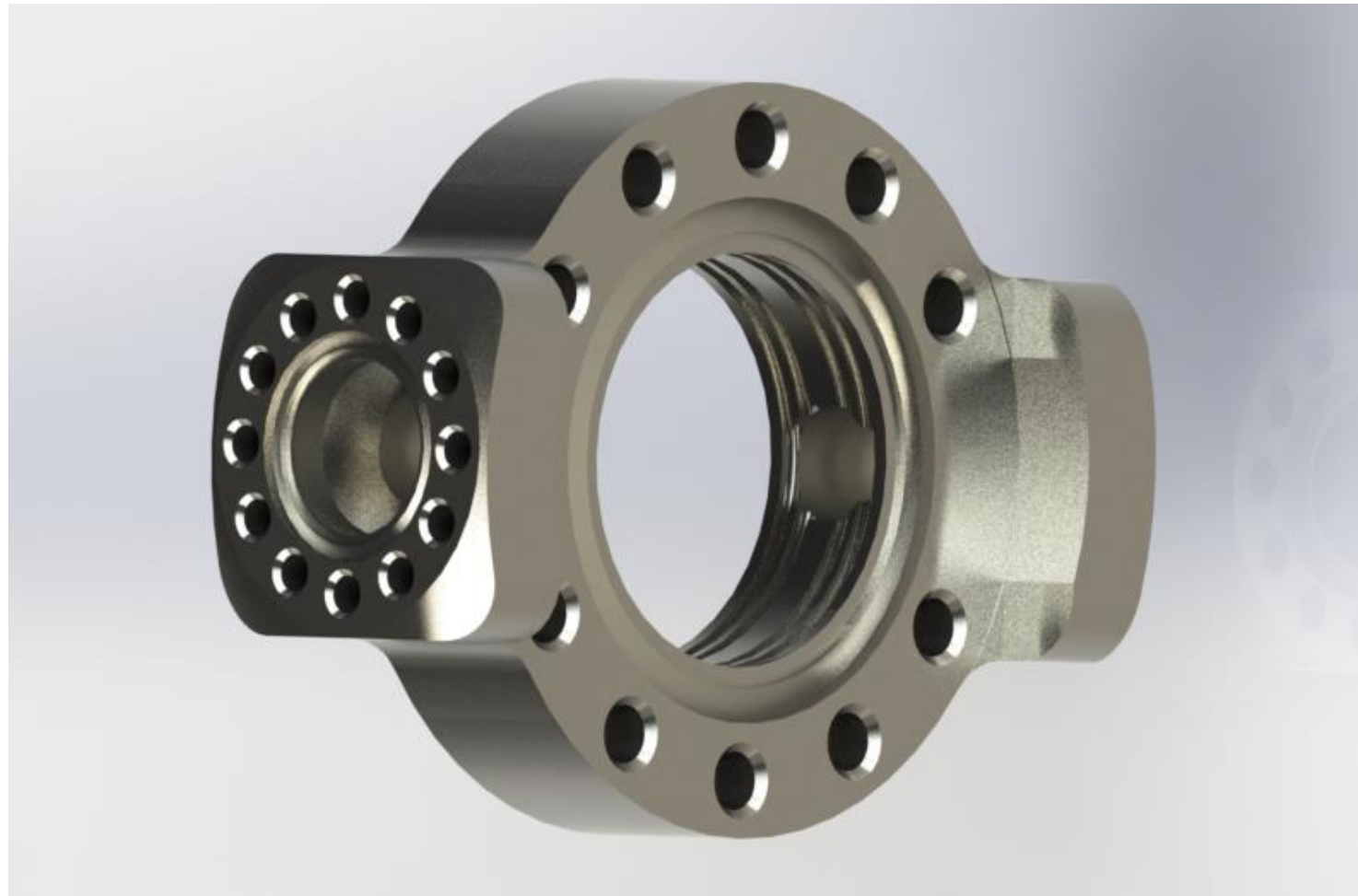


# My Design

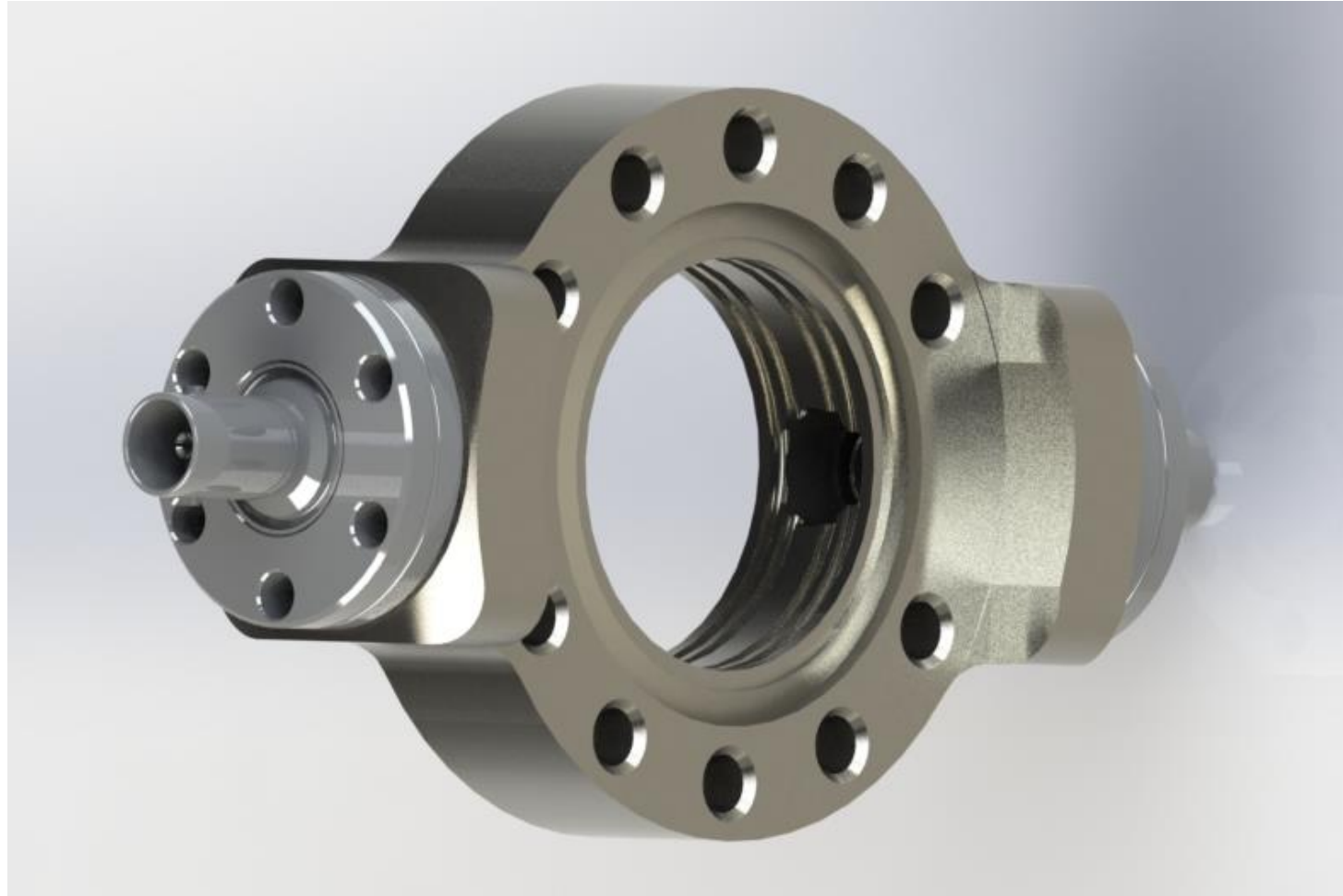
- Many pre-built parts
- Secure plate mounting
- Prevents plates from sagging
- Provides electrical connections
- UHV compatible parts
- Easy installation



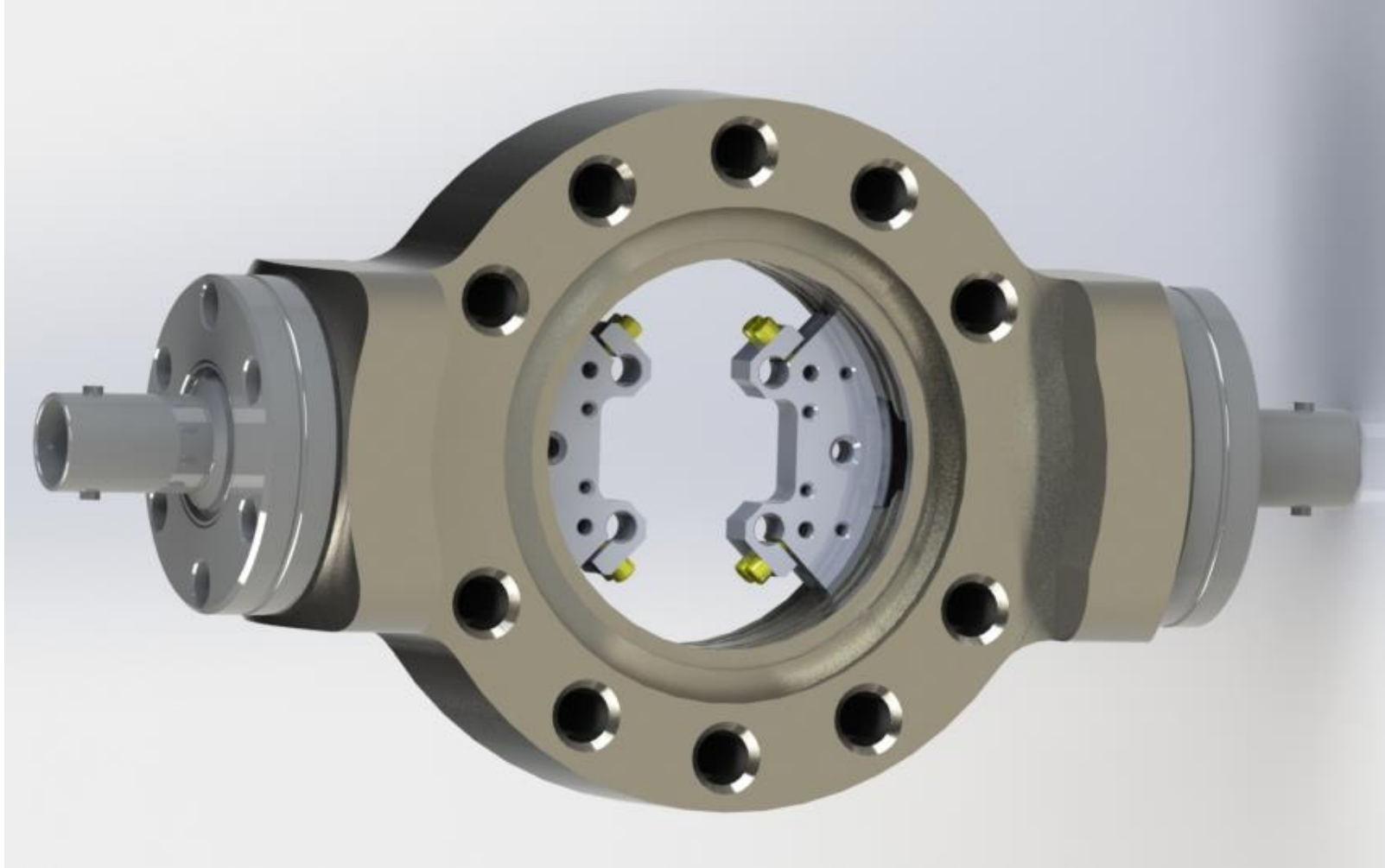
# My Design



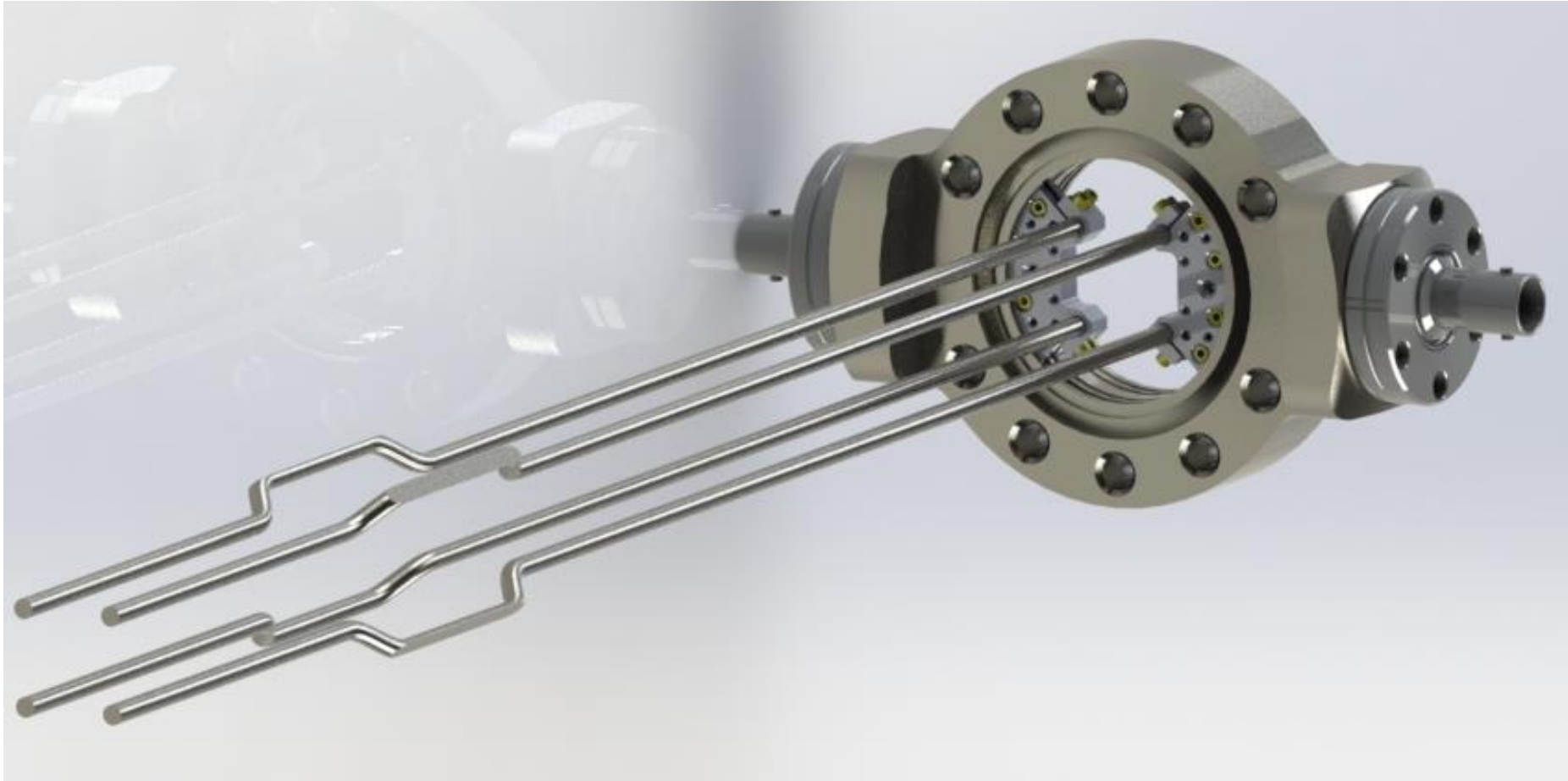
# My Design



# My Design

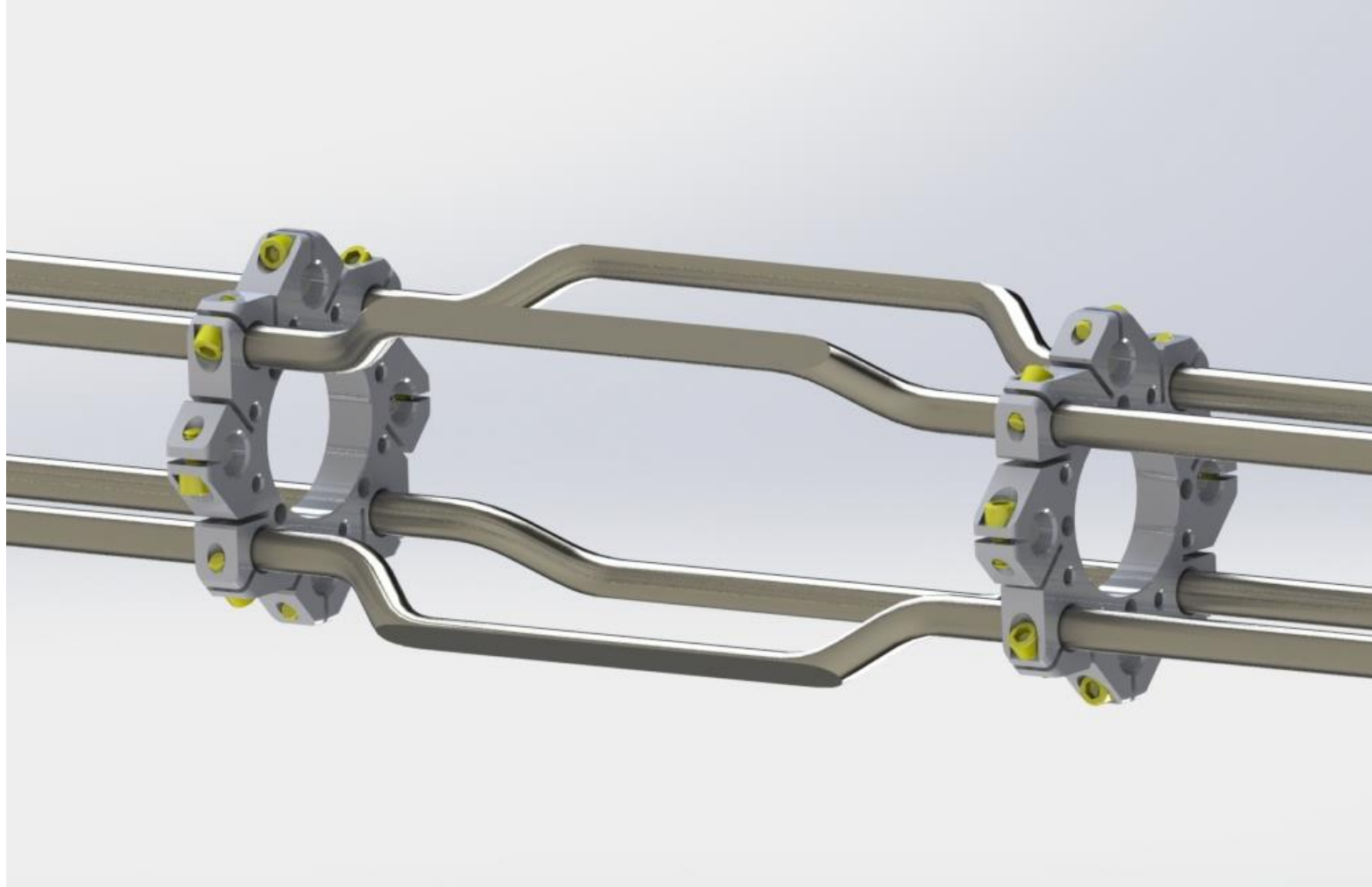


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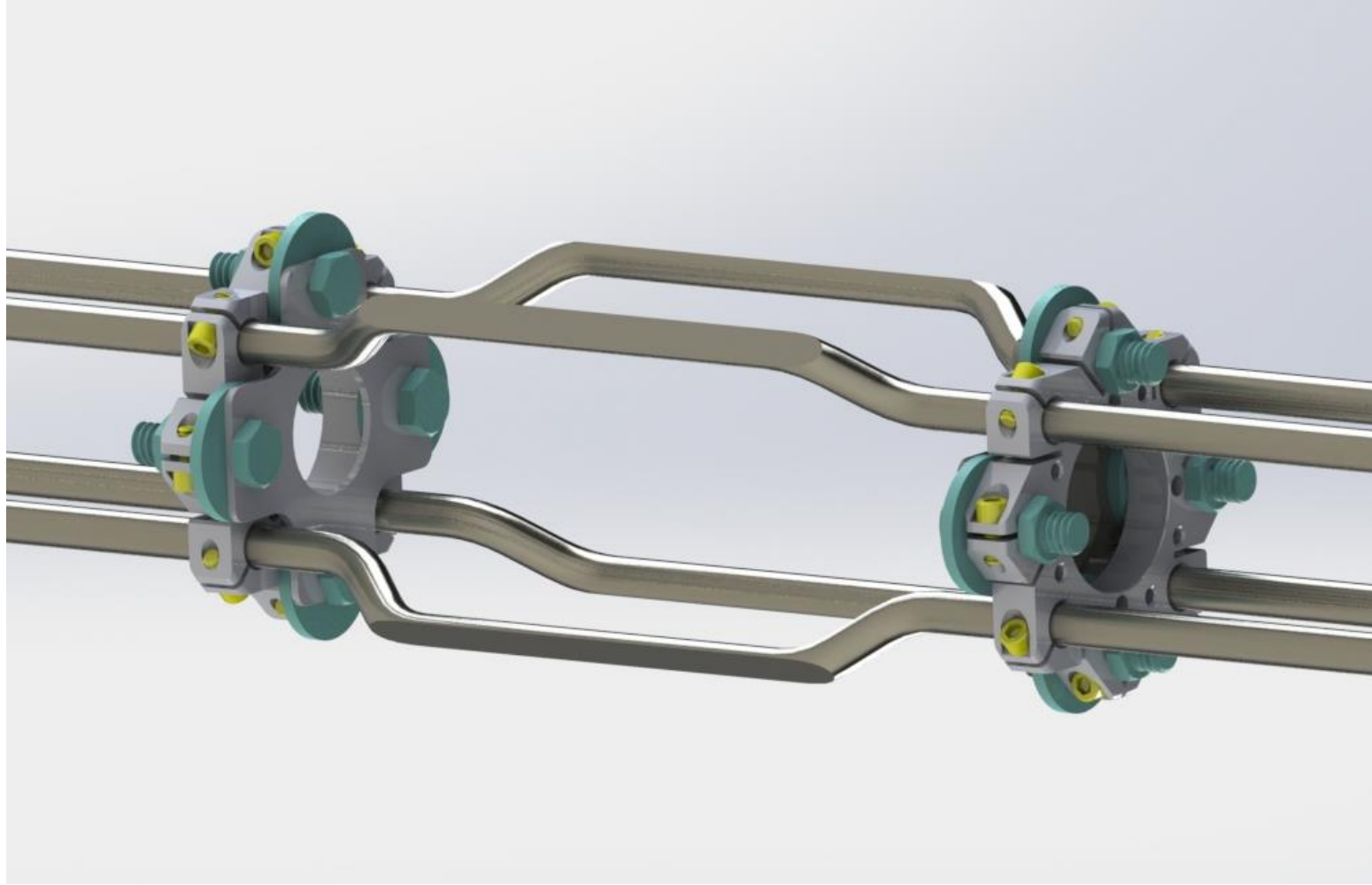




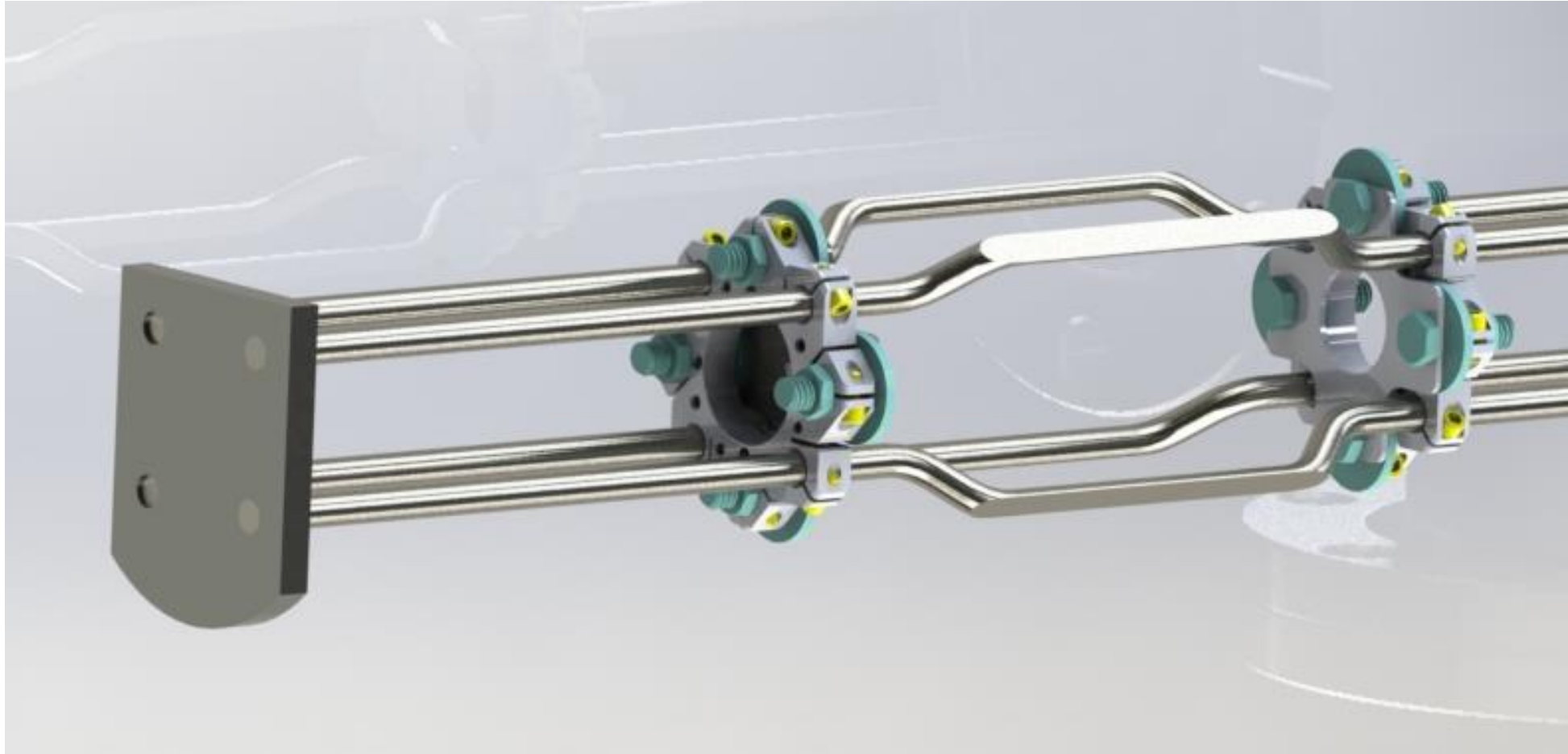
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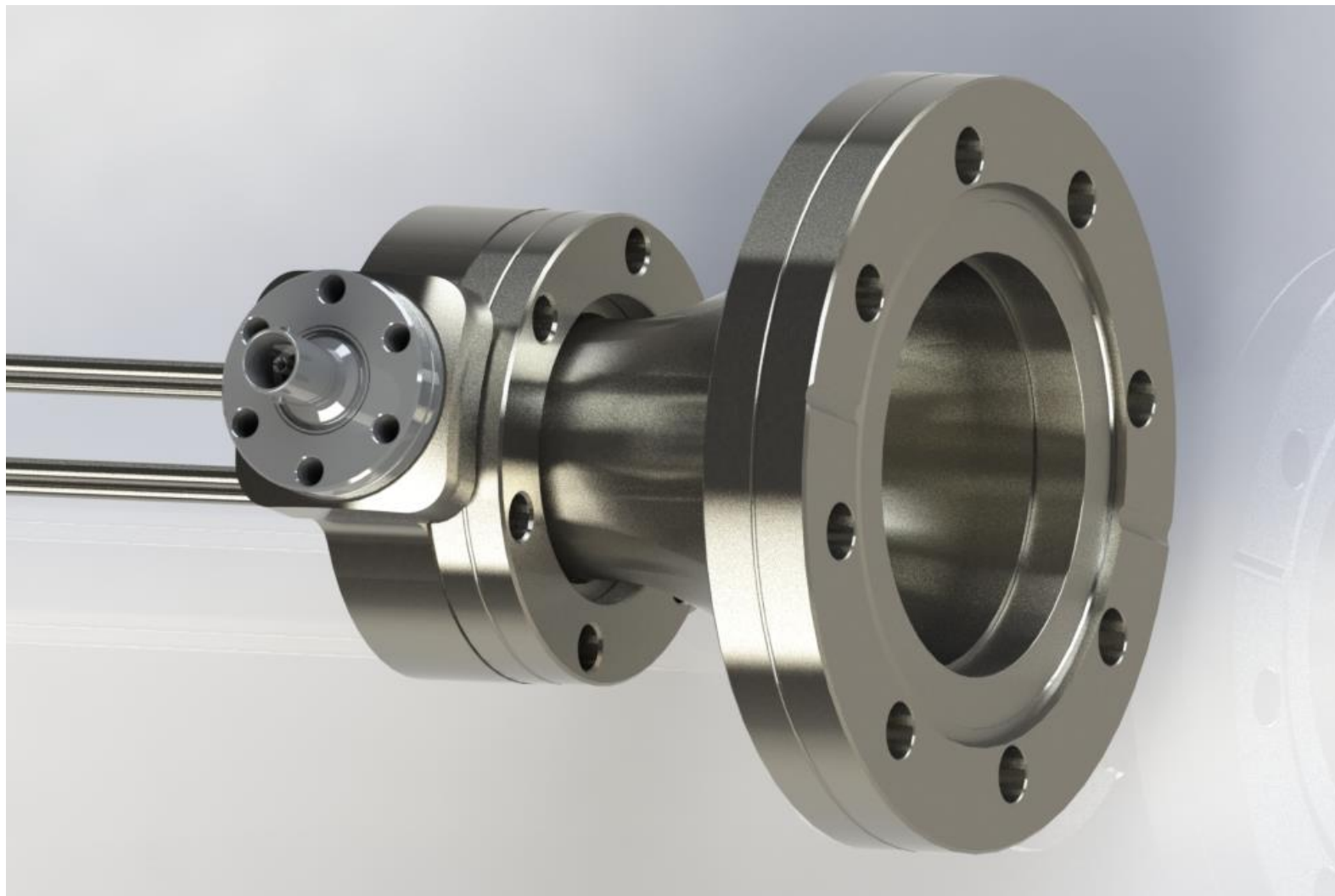
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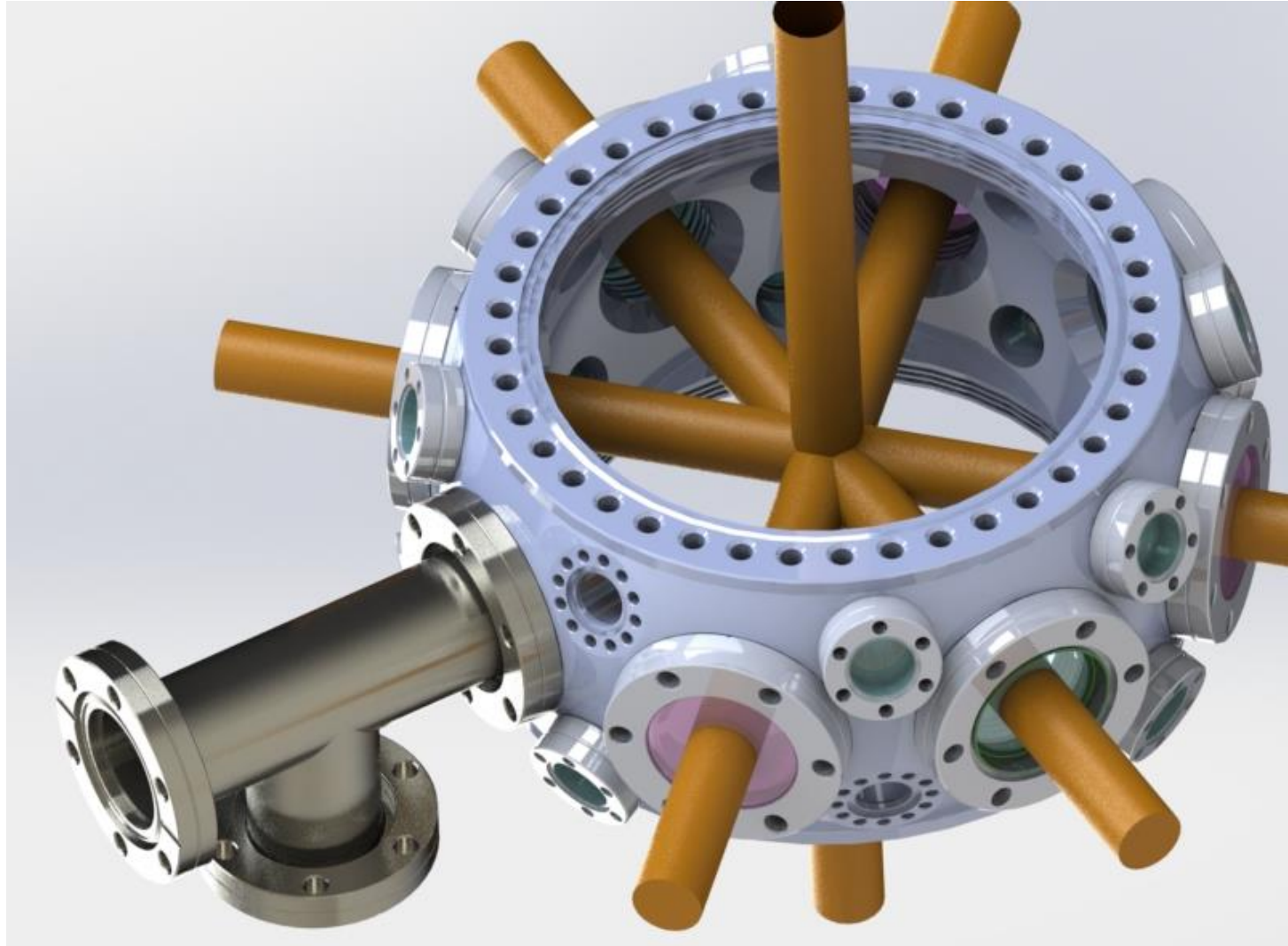
# My Design



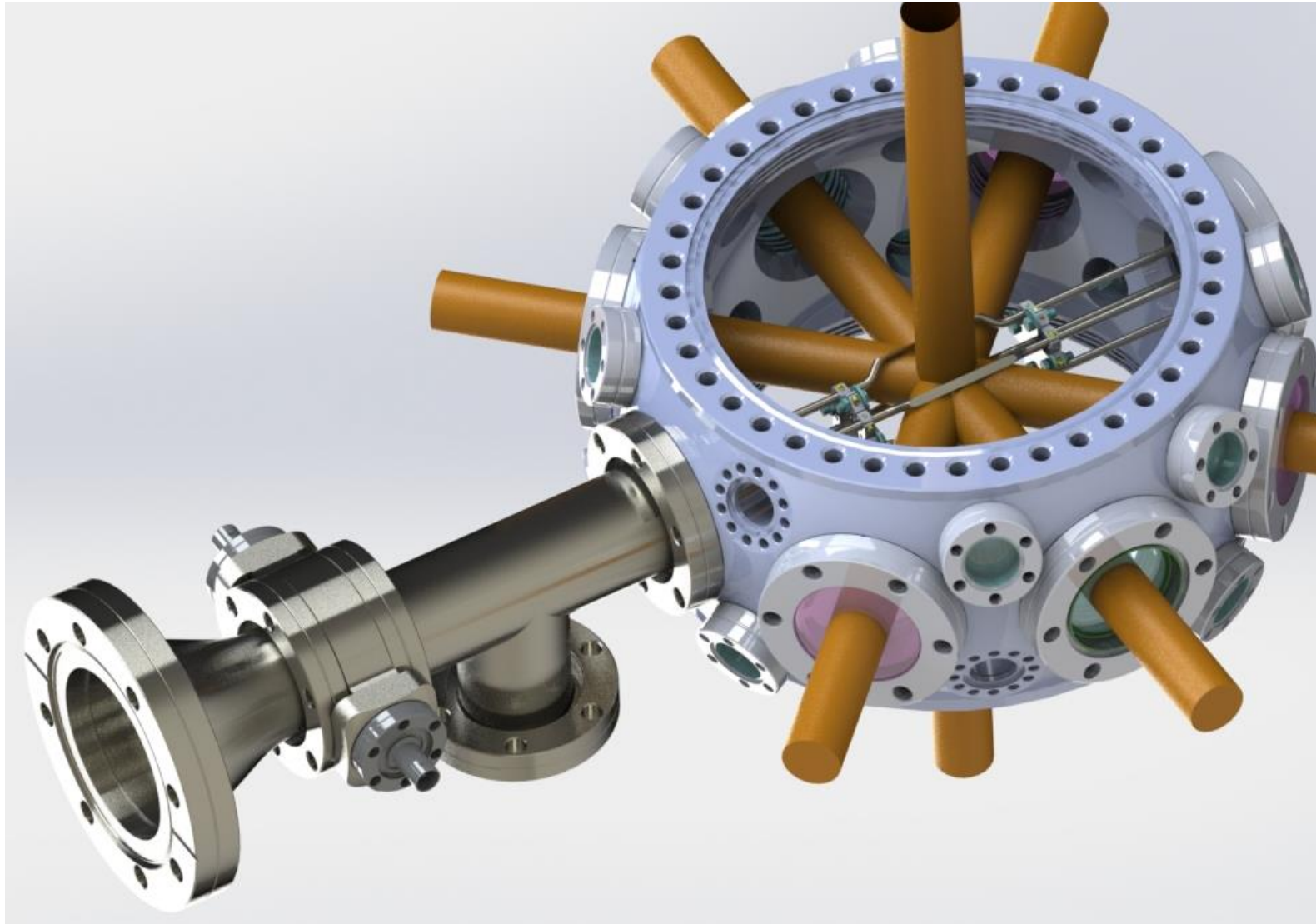
# My Design



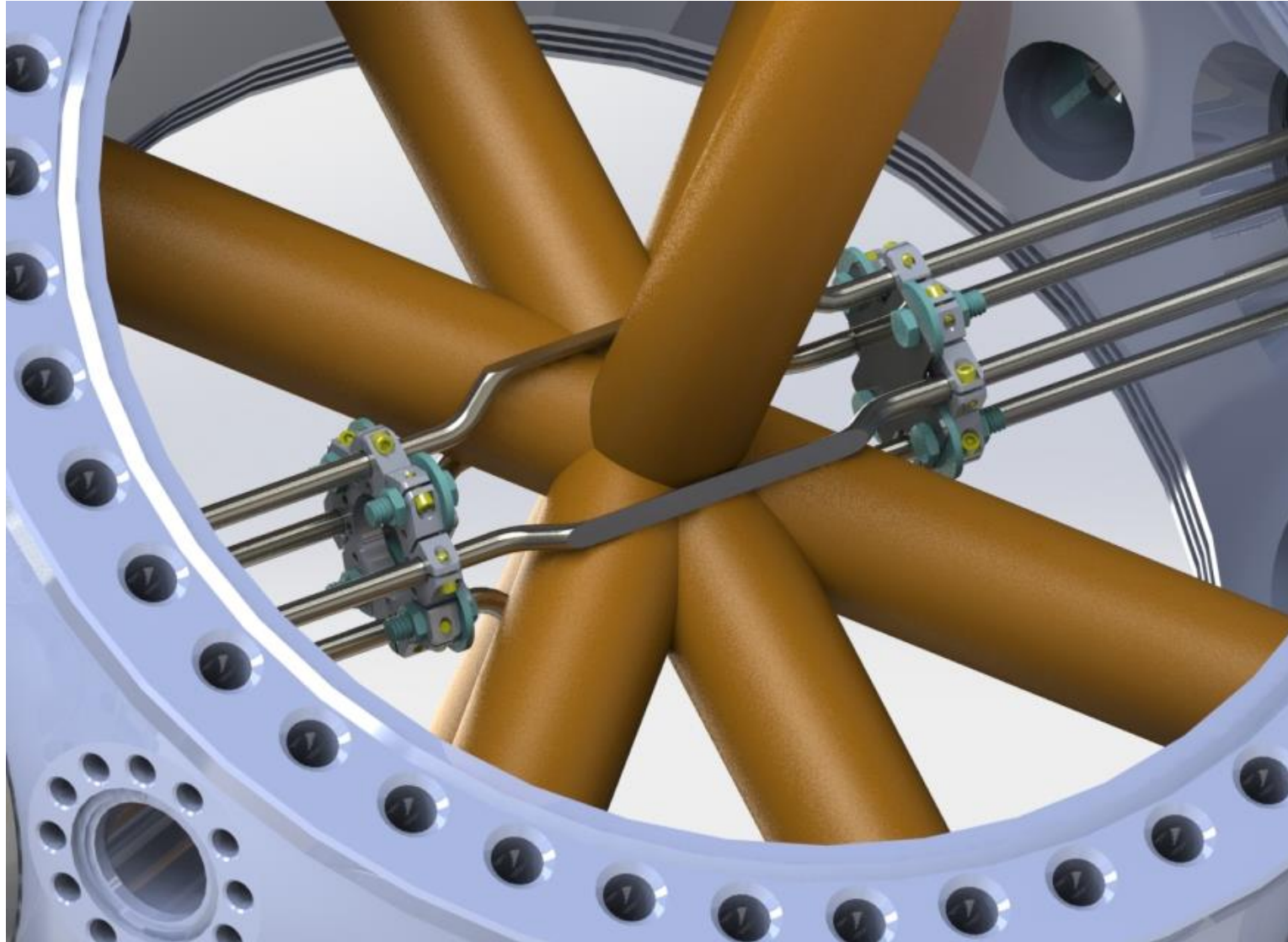
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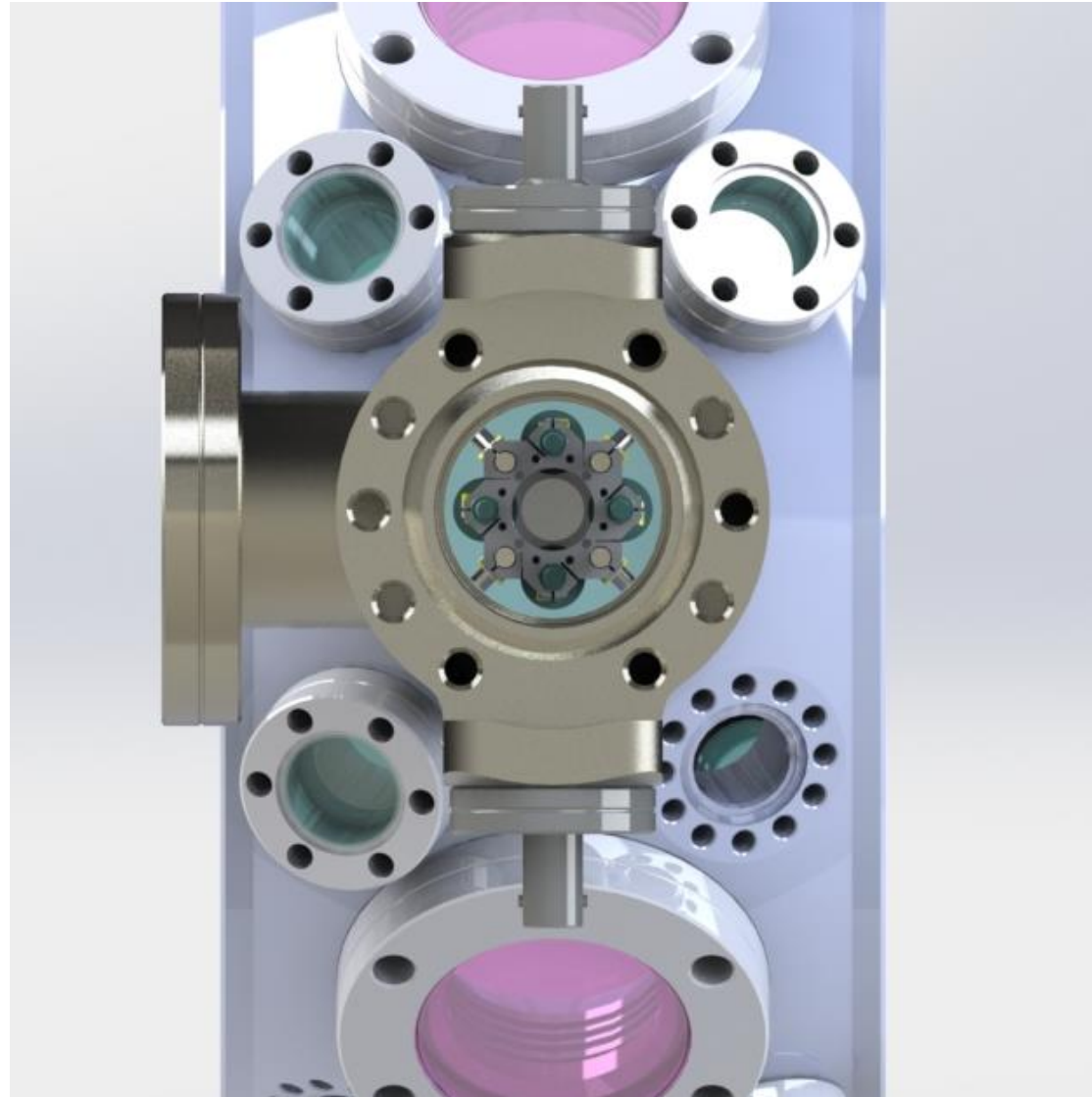
# My Design



# My Design

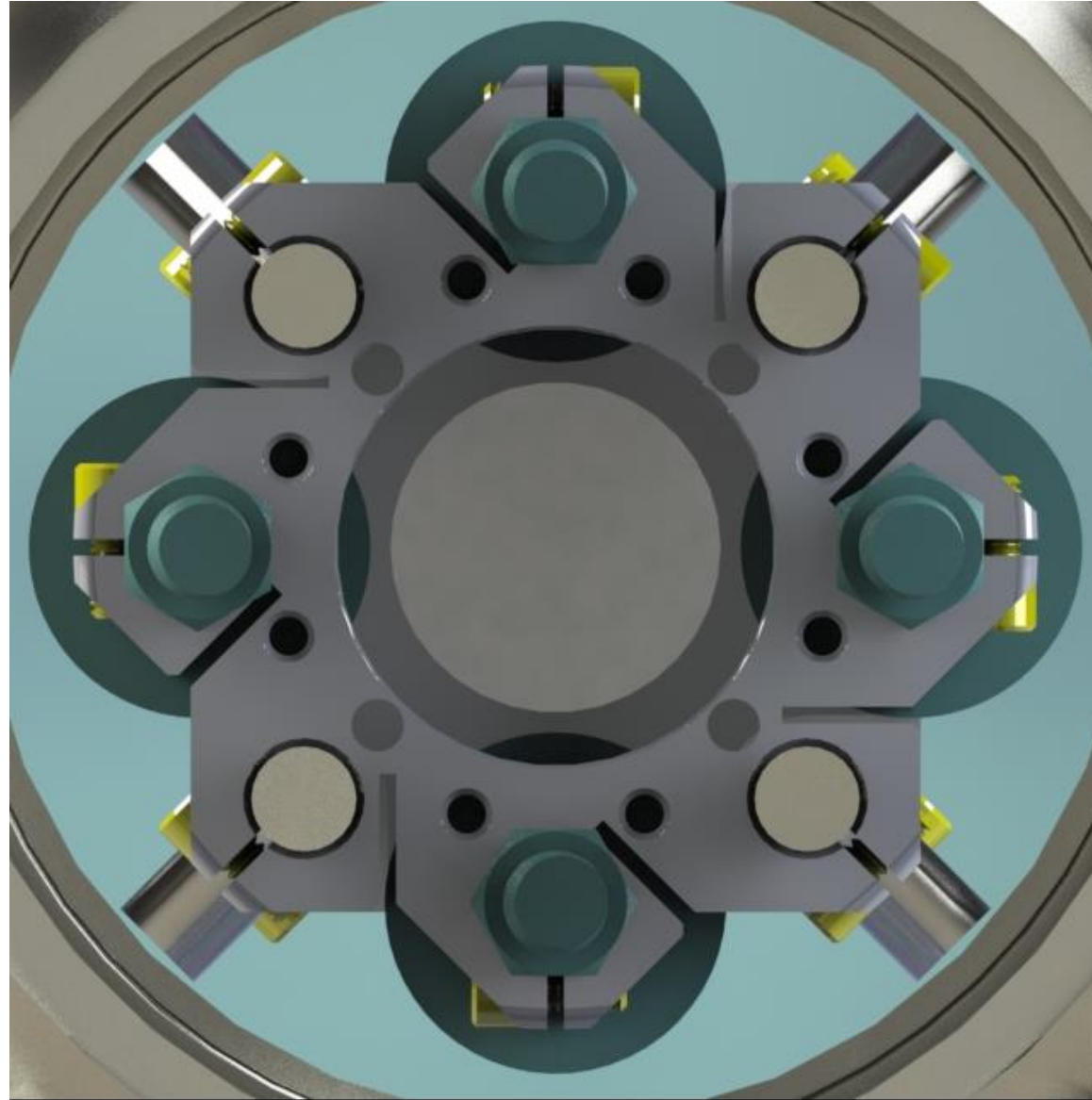


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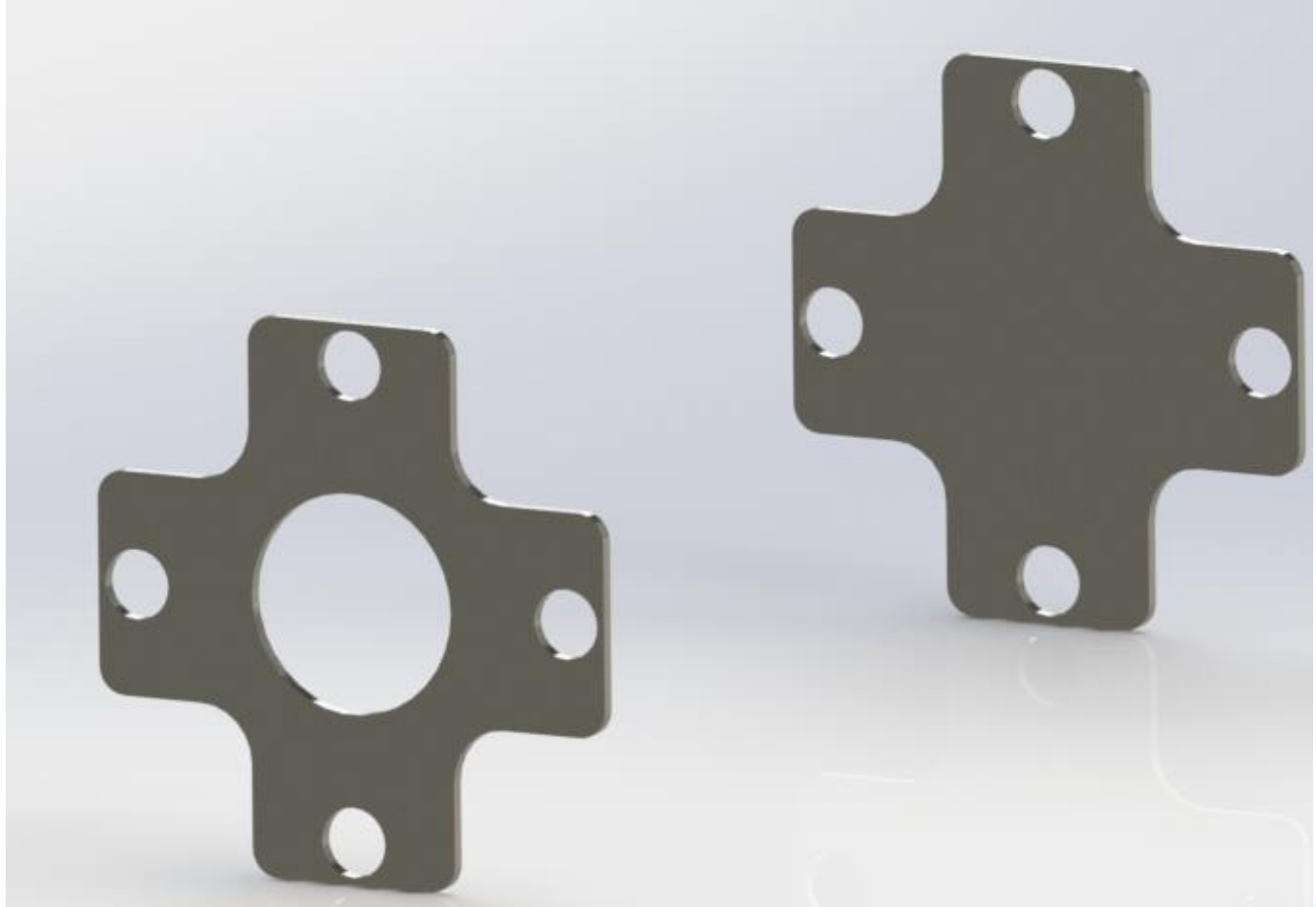


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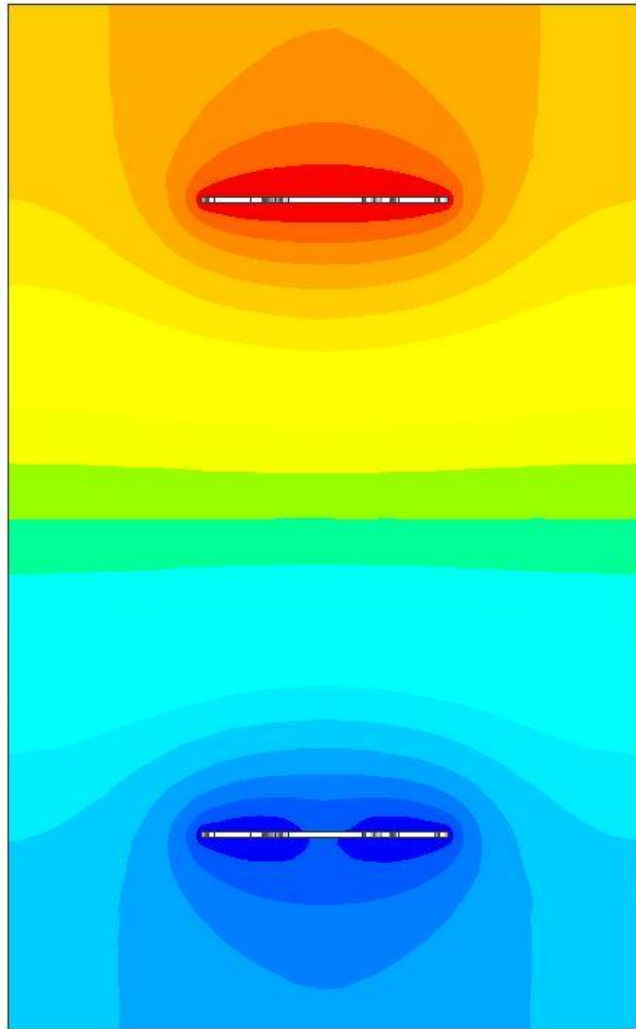


# Final Plate Configuration

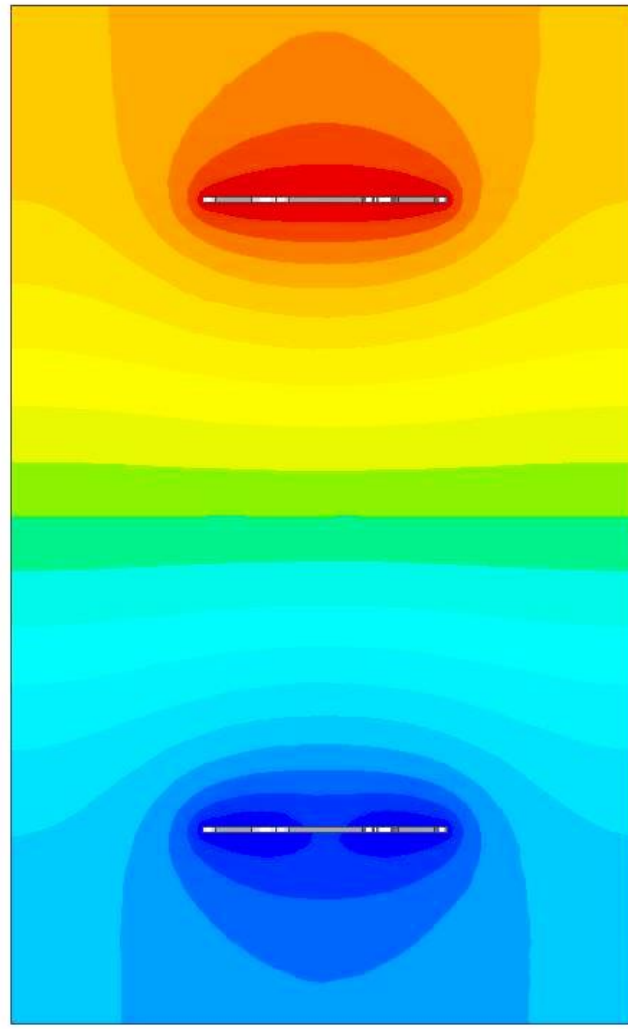
- 0.635 mm thick stainless steel
- 6.50 cm plate separation
- 1.00 cm hole in bottom plate
- 0.318 cm holes for Alumina bolts



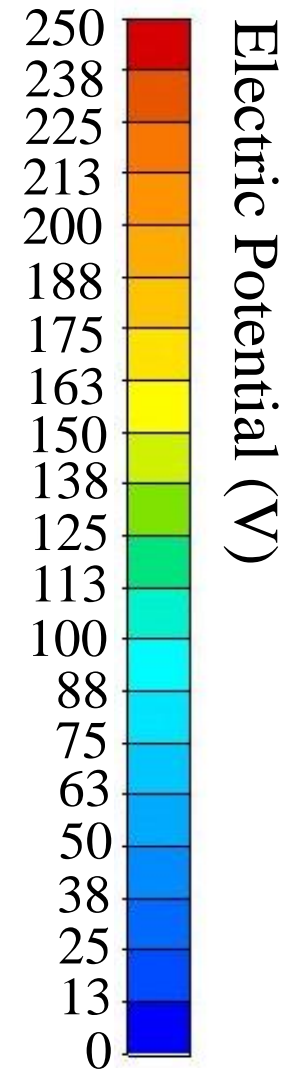
# Final Plate Electric Potentials



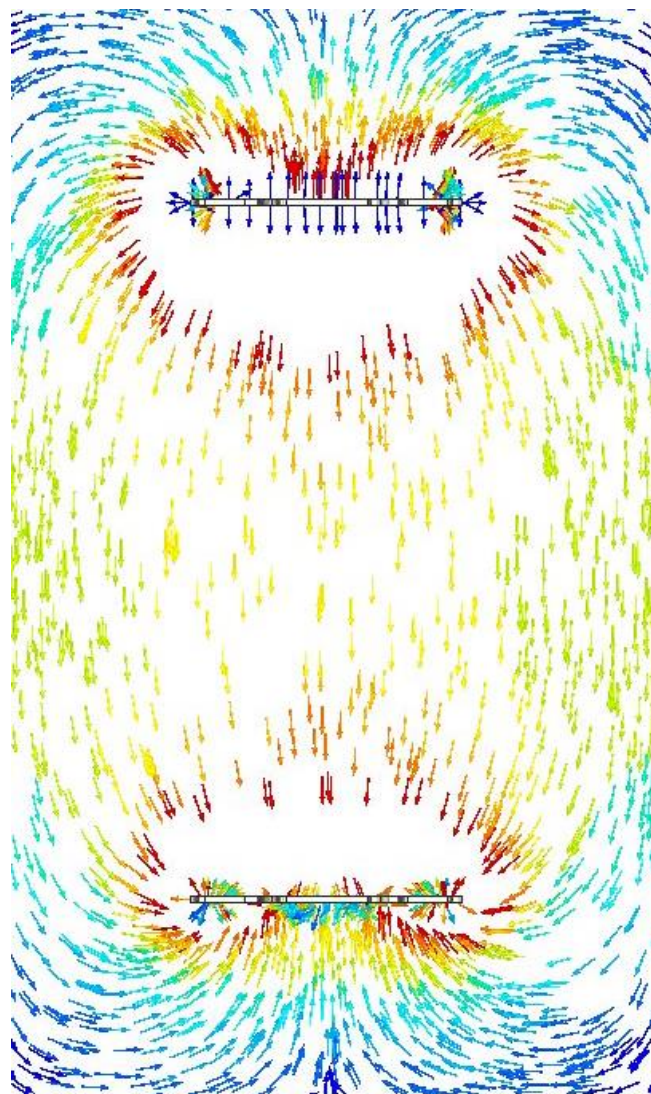
XZ Plane



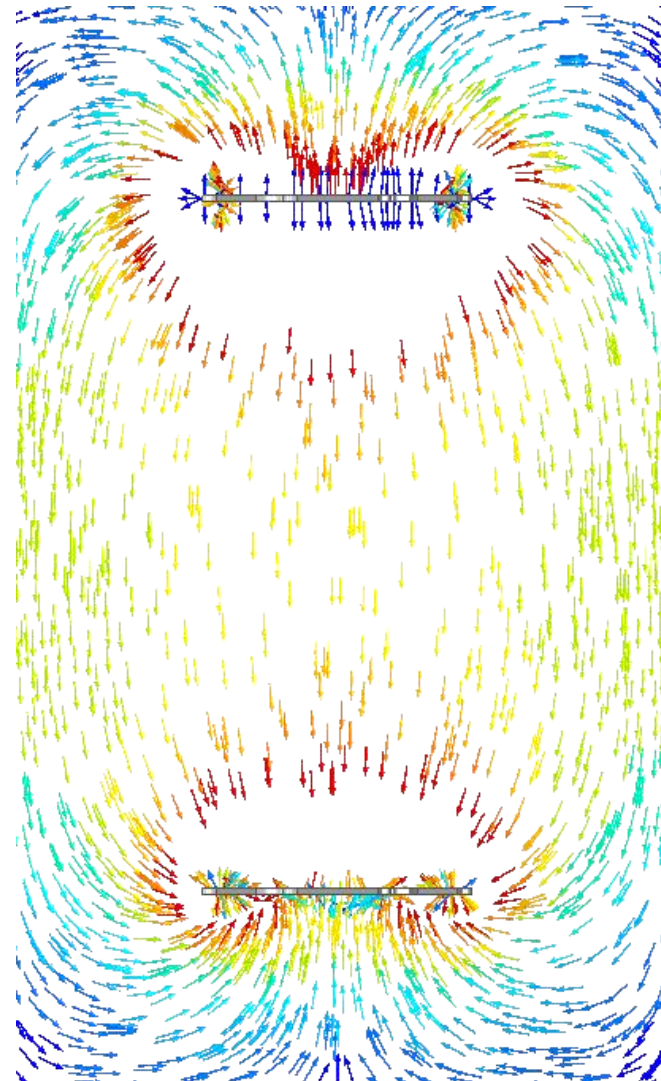
YZ Plane



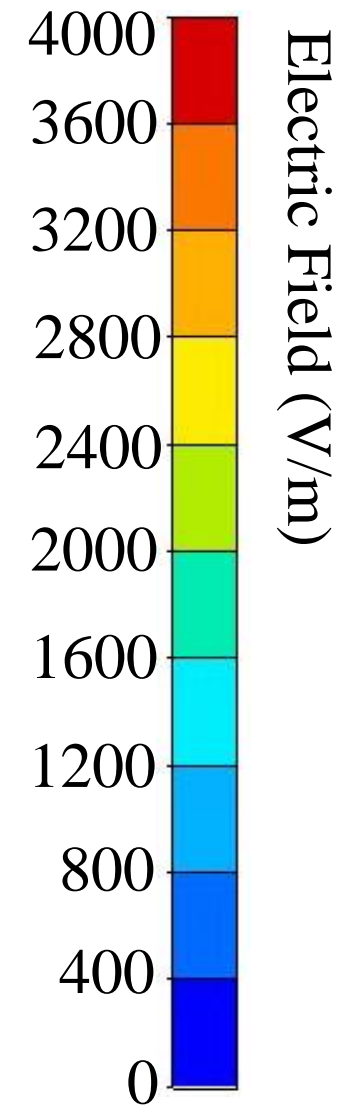
# Final Plate Electric Fields



XZ Plane

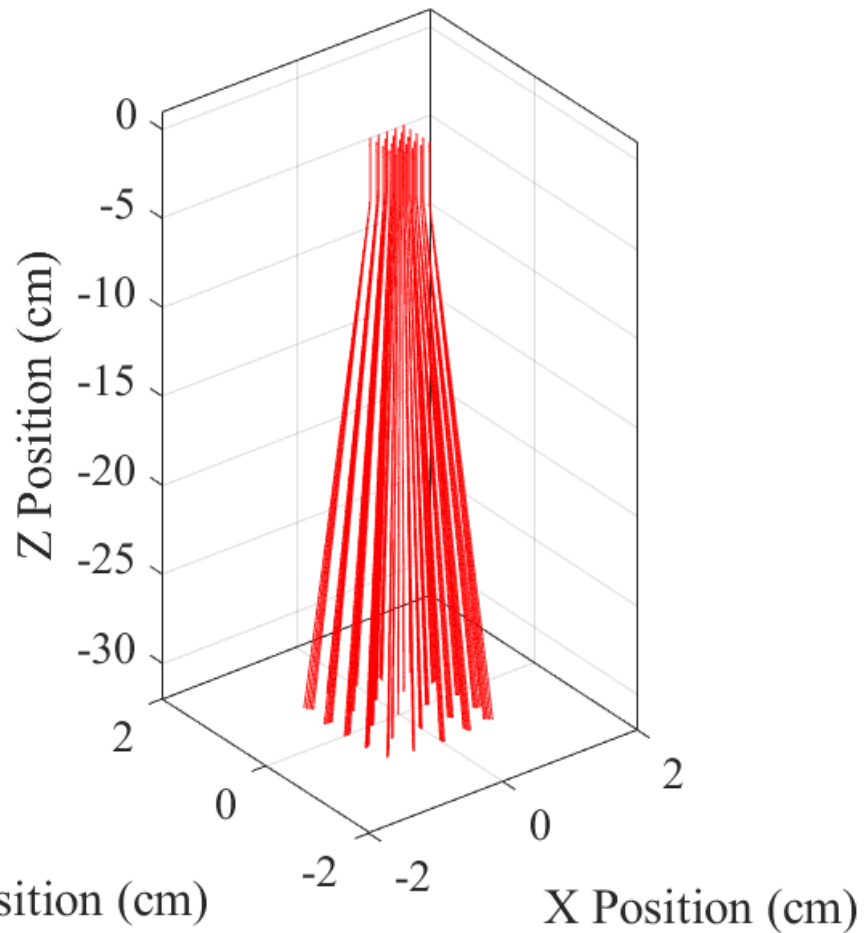


YZ Plane

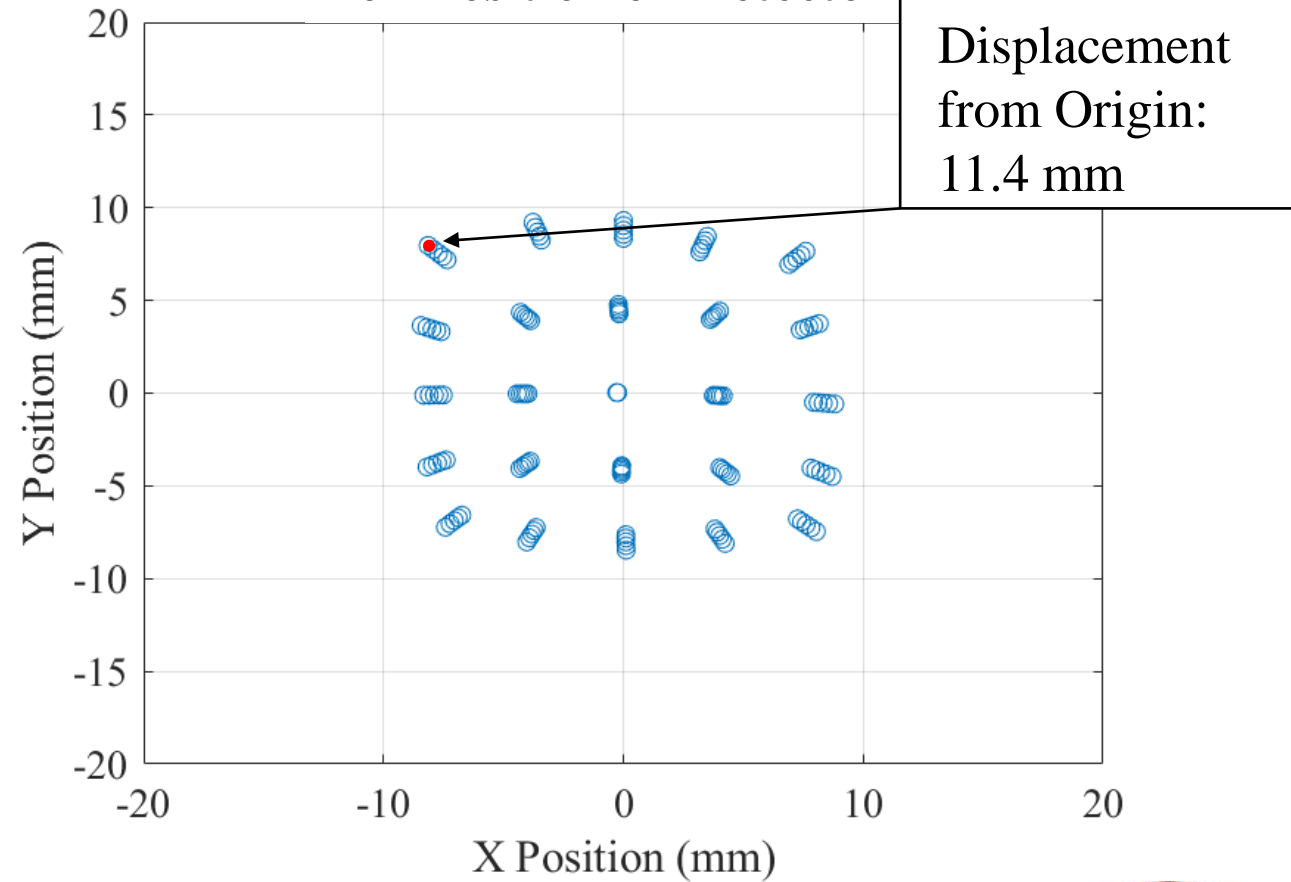


# Final Plate Configuration

## Ion Trajectories



## Ion Position on Detector



# Conclusion and Outlook

- Designed a pulse-field ionization spectrometer
- Design fits geometric constraints
- Simulated the electric field created by the plates
- Simulated the trajectories of the Rydberg impurities
- Provided parts list to purchase parts
- Provided 2D drawings to fabricate parts
- Microchannel Plate detector needs to be selected
- Allows for experimentation on Rydberg impurities in sodium spinor BECs



# Questions?

