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Design and Modeling of Dark Matter Axion Detectors

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QuarkNet Summer Program

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Outline

- Background on me
- Dark matter axions
- The ADMX experiment
- My contributions to experiment
- Acknowledgments

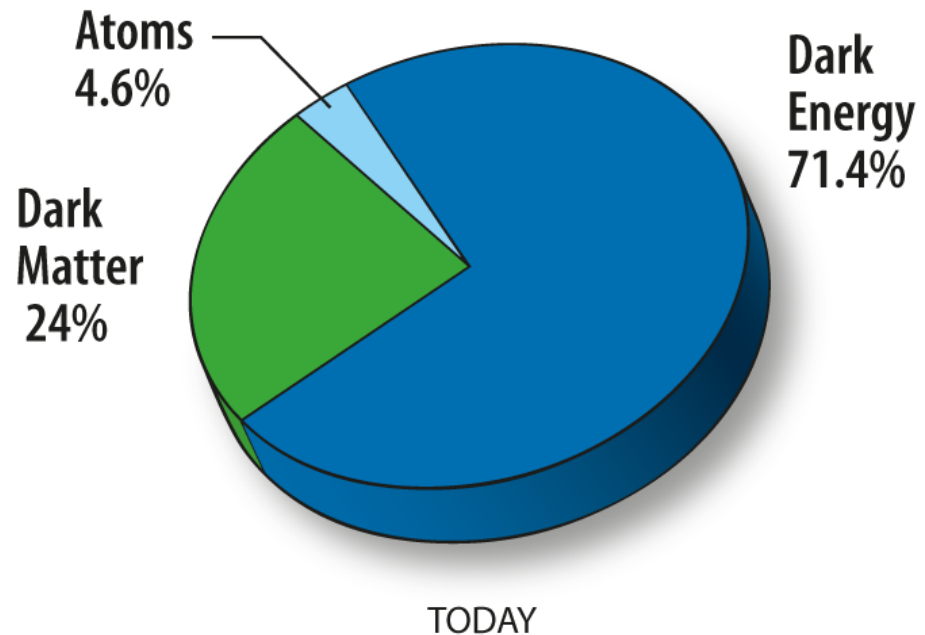
Who am I?

- High school senior
- Oak Park and River Forest High School
- Interested in aerospace engineering



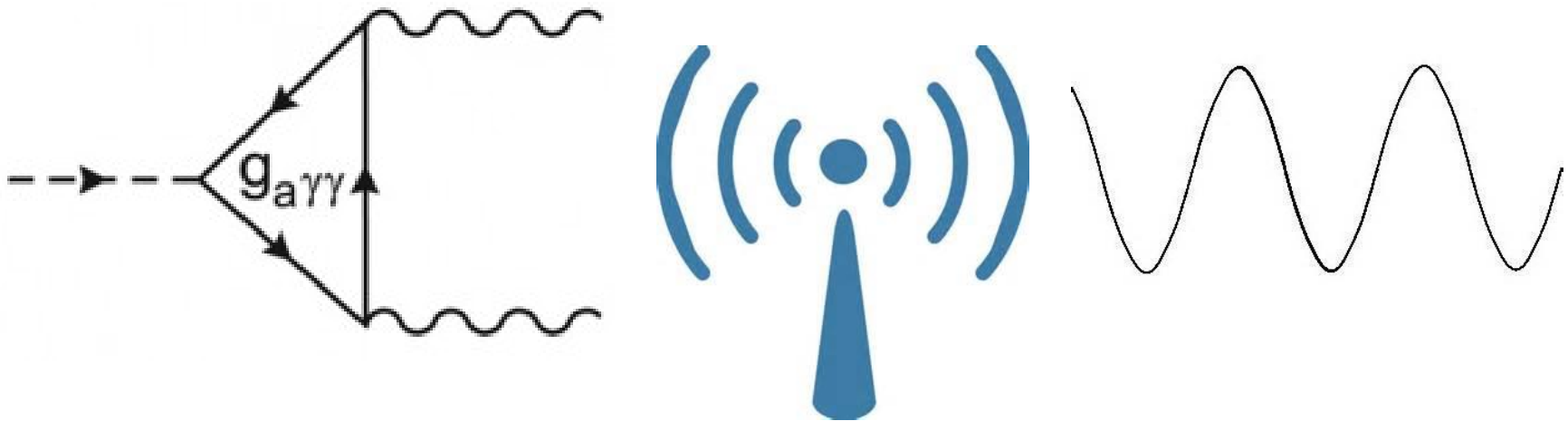
Dark Matter

- Makes up 24% of observable mass/energy
- Does not interact or emit electromagnetic radiation
- Likely made of particles



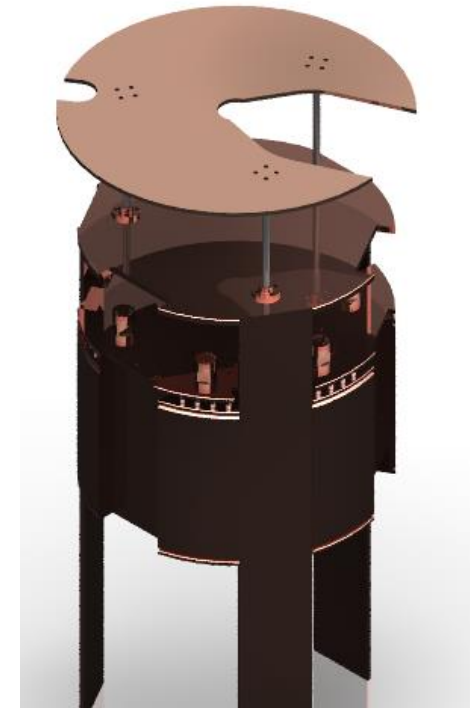
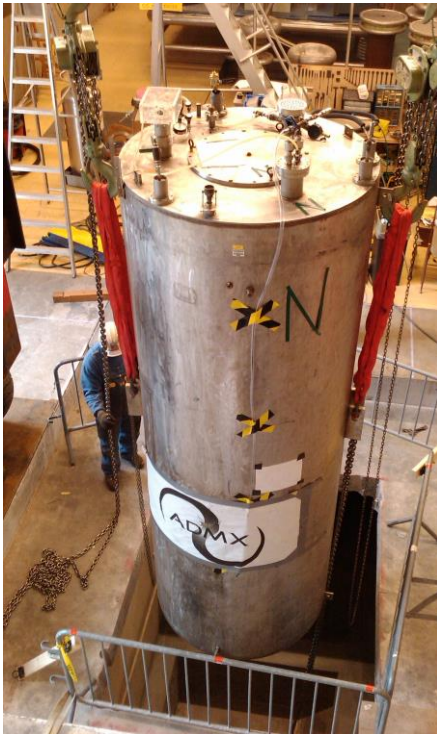
Principle of Axion Detection

- Low temperature microwave cavities in strong magnetic field
- Axion microwave photon coupling
- Microwave photon detection



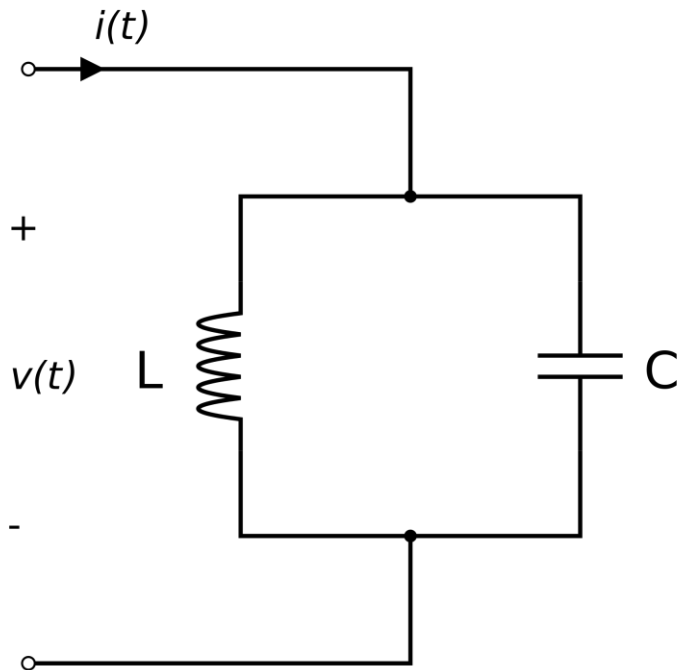
Existing Axion Search Experiments

- ADMX (Axion Dark Matter eXperiment)
- Sidecar experiment
- Fermilab high frequency R&D



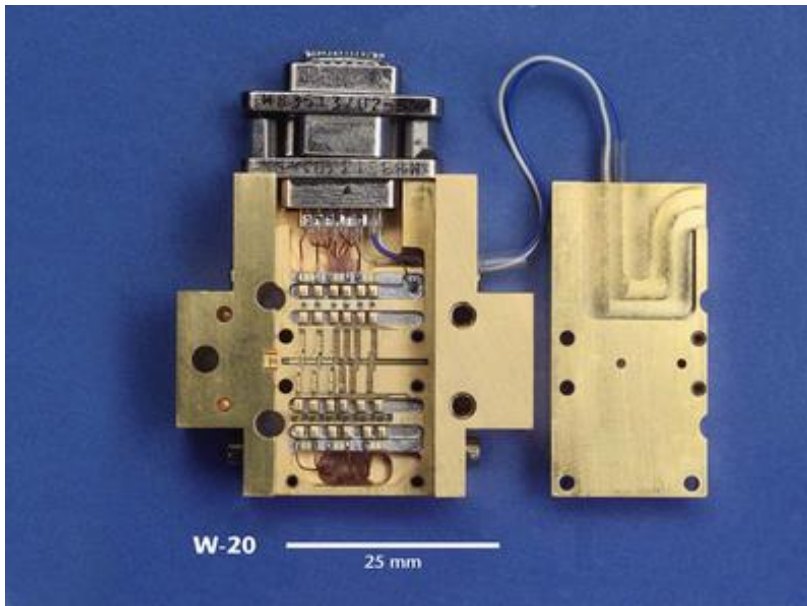
How Does ADMX Work?

- Microwave cavities
- Inductor/capacitor circuit
- “Listening” for signal

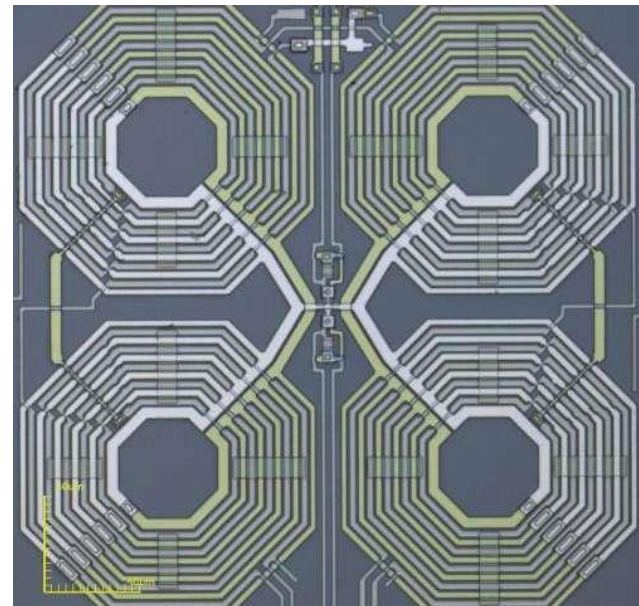


Low Noise High Power Amplification

- Power signature at Yoctowatt scale (10^{-24} watts)
- HFETs
- SQUIDS

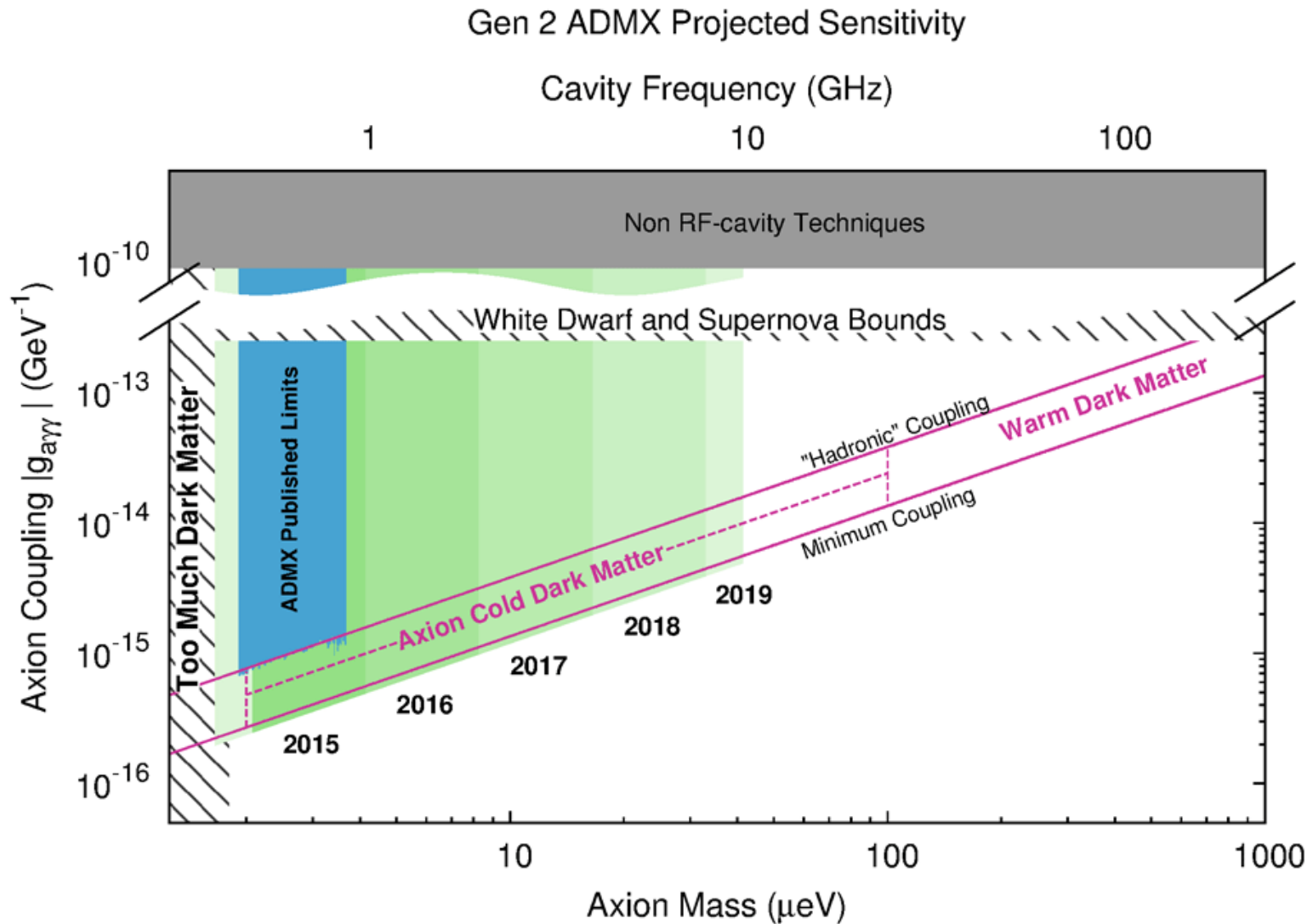


HFET Amplifier

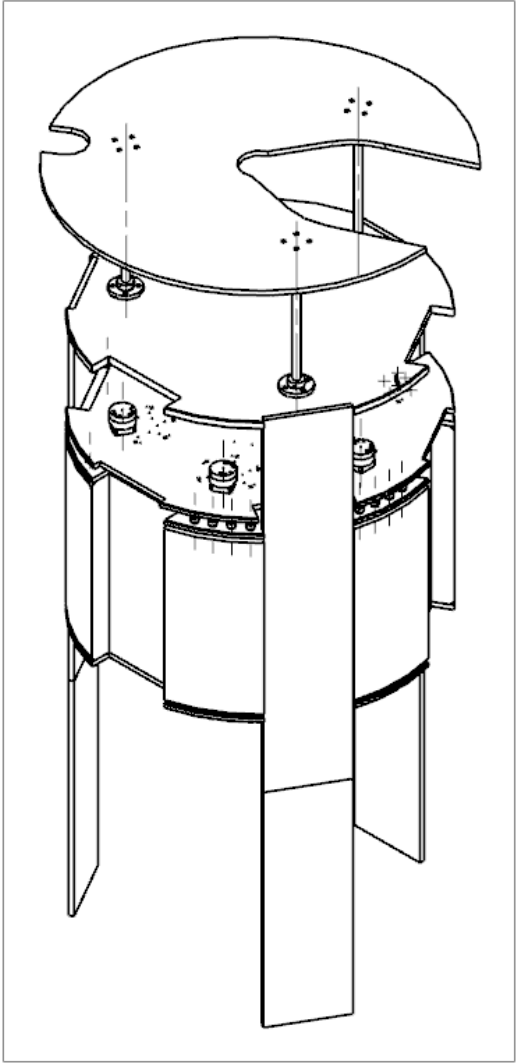
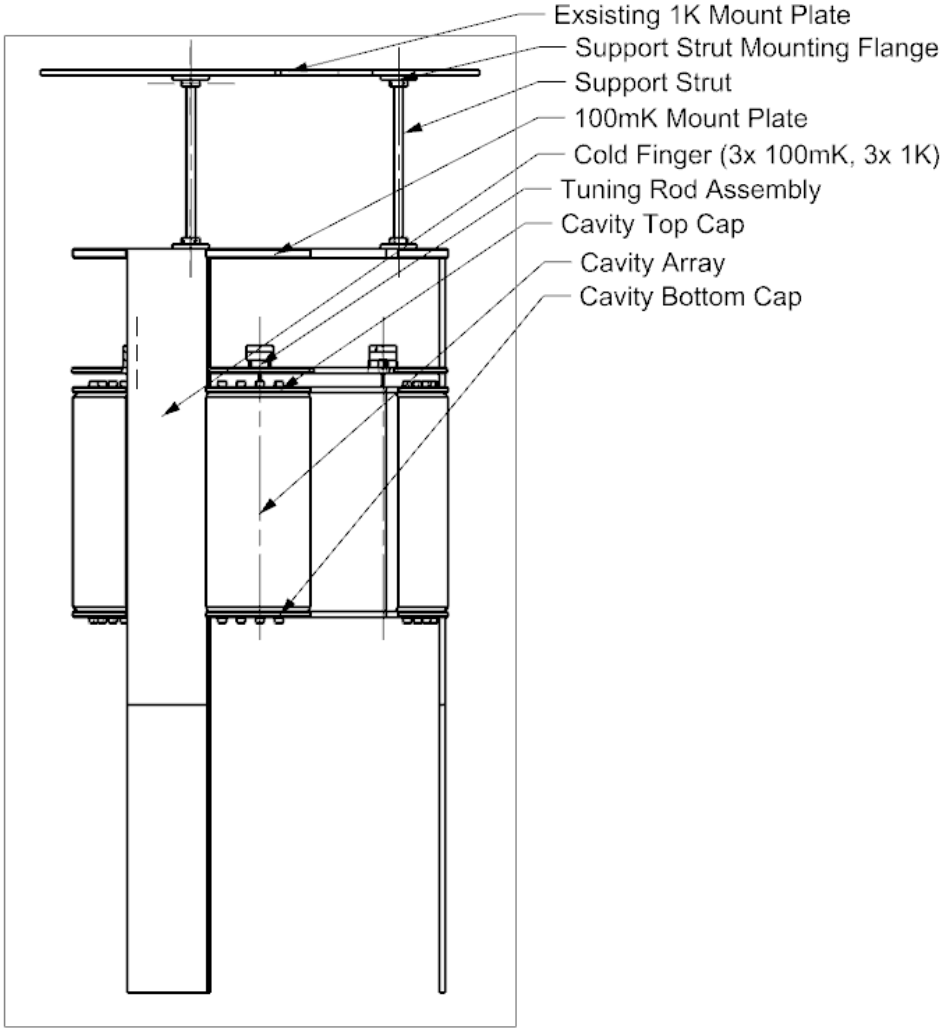


Squid Amplifier

ADMX Results



High Frequency Detector Design

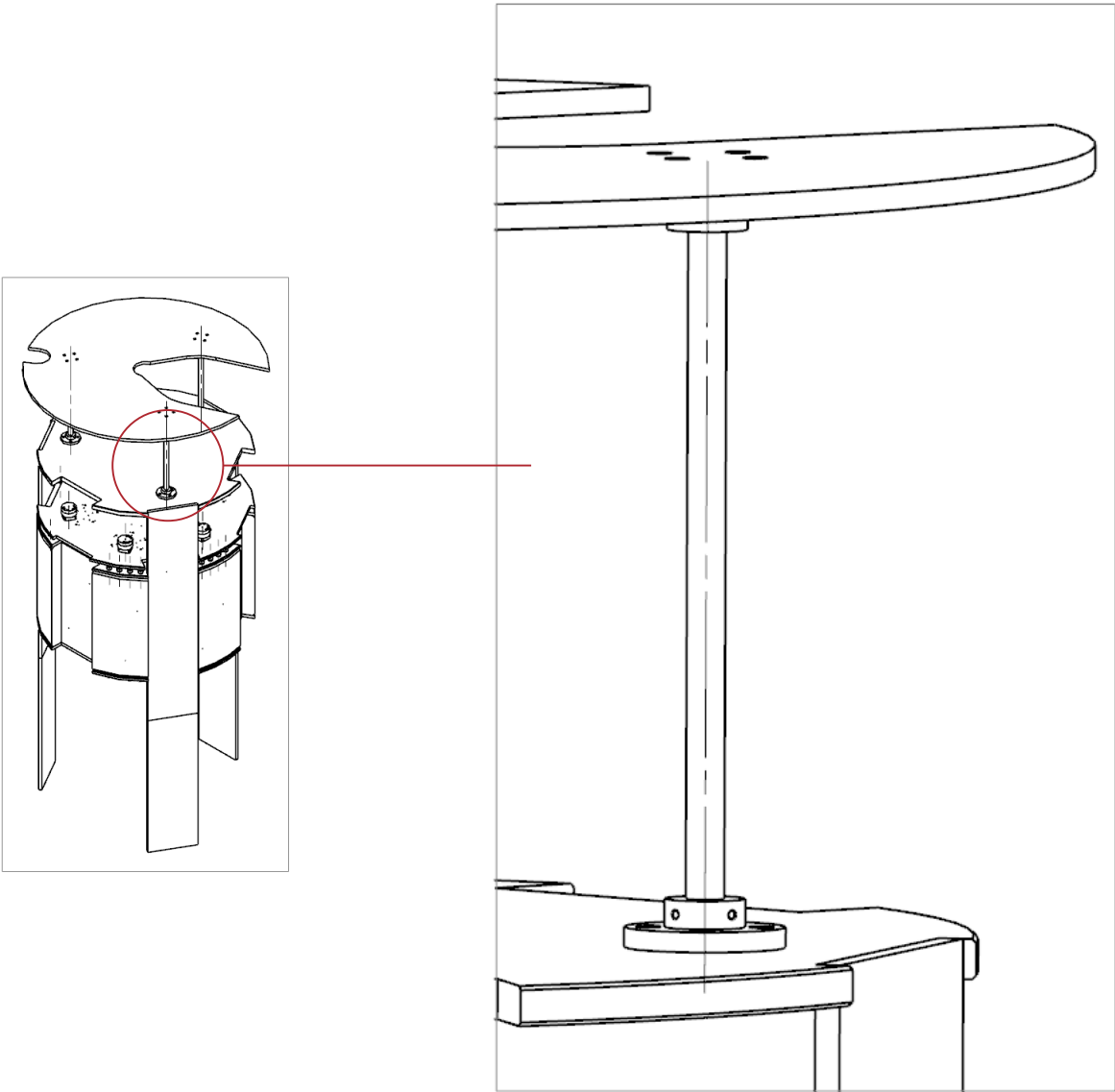


Parameter Based Models

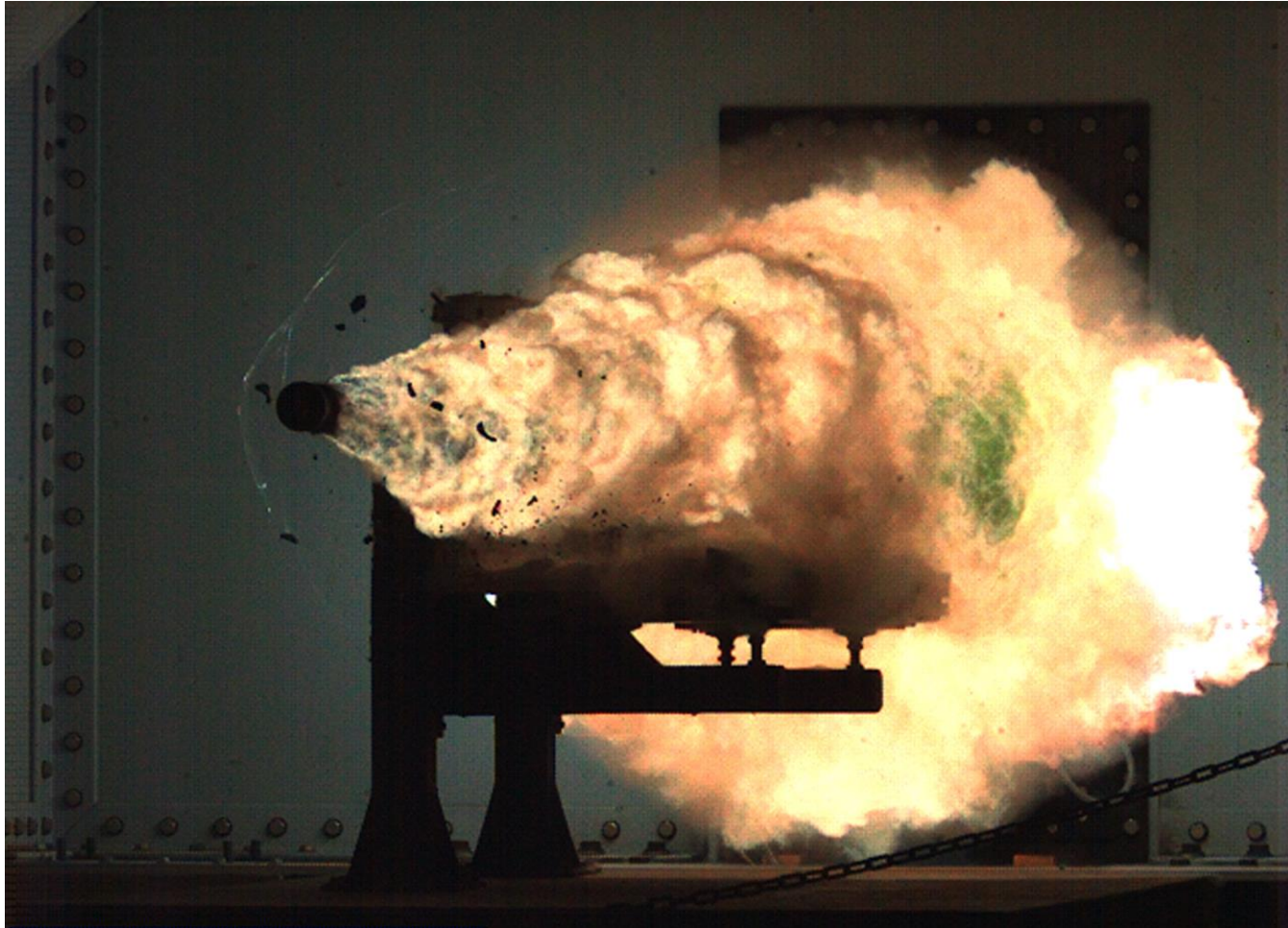
# of Cavities in Line (3 for 7, 5 for 19, 7 for 37)	Diameter of Cavity Chamber (mm)	Diameter of Cavity (mm)	Thickness of Cold Finger (in)	Width of Cold Finger (in)
3	426	120	0.25	4
5	426	70	0.25	4
7	426	43	0.25	4
Is Cavity Diameter Too Big?		Thickness of Cold Plates (mm)	Thickness of Caps (mm)	
No		6.35	6.35	
No		6.35	6.35	
No		6.35	6.35	

Diameter of Bearing Hole (mm)	Hole Offset (mm)	Hole Diameter (in)	Antennea Diameter (mm)
5	24	0.375	5
5	14	0.375	5
5	8.6	0.375	5
Tuning Rod Diameter (mm)	Tuning Rod Armature Length (mm)	Antennea Offset (mm)	Tuning Rod Length (mm)
24	36	33.9411255	238
14	21	19.79898987	138
6.4	12.9	12.16223664	84

Connection to Existing ADMX Equipment

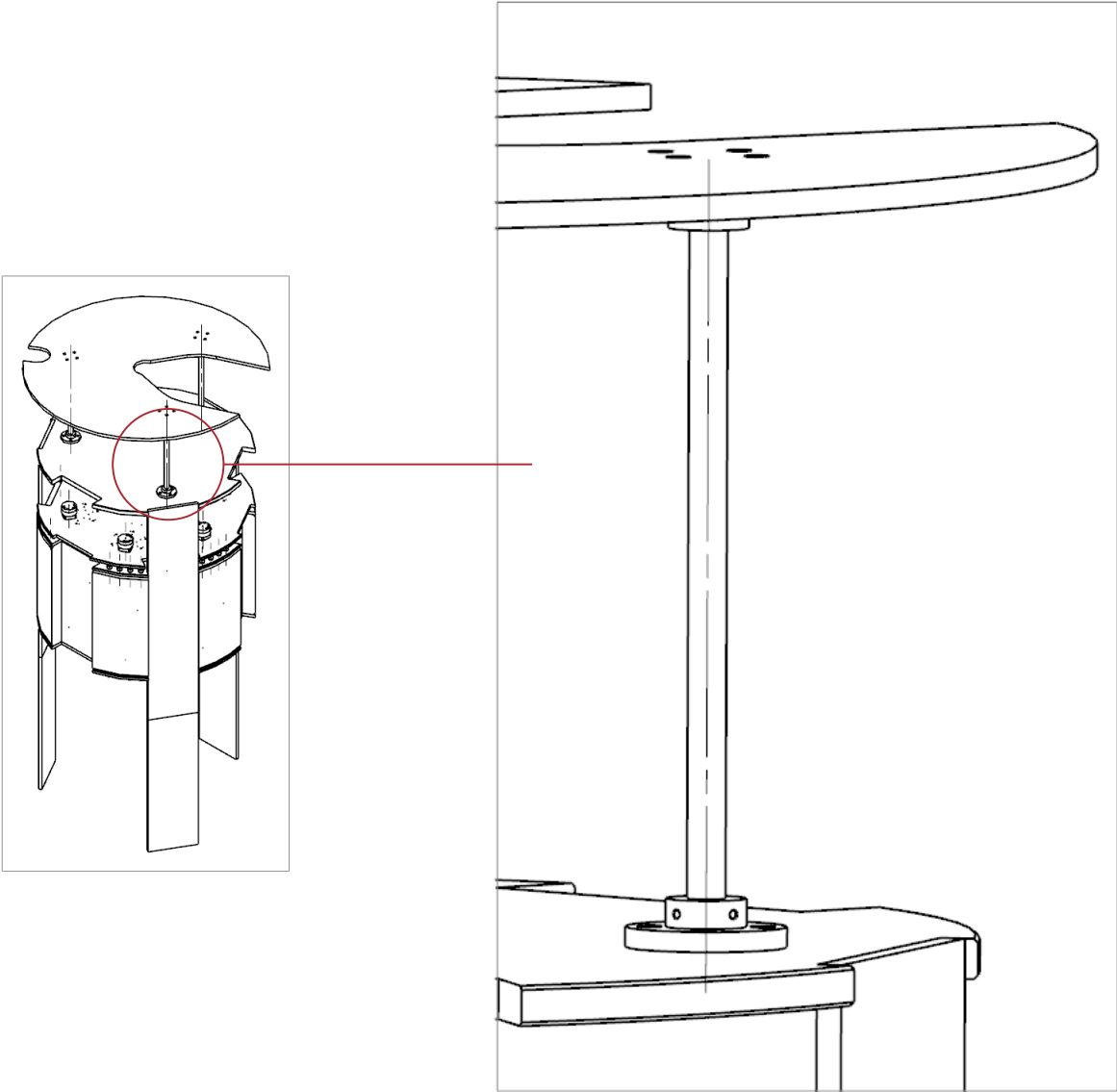


Connection to Existing ADMX Equipment



Railgun test courtesy of US Navy

Connection to Existing ADMX Equipment

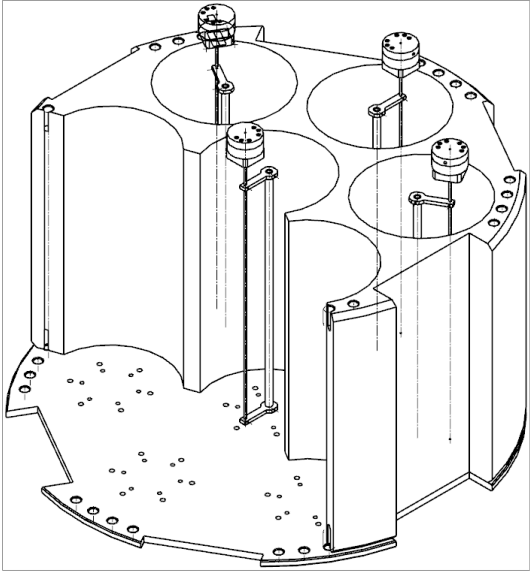
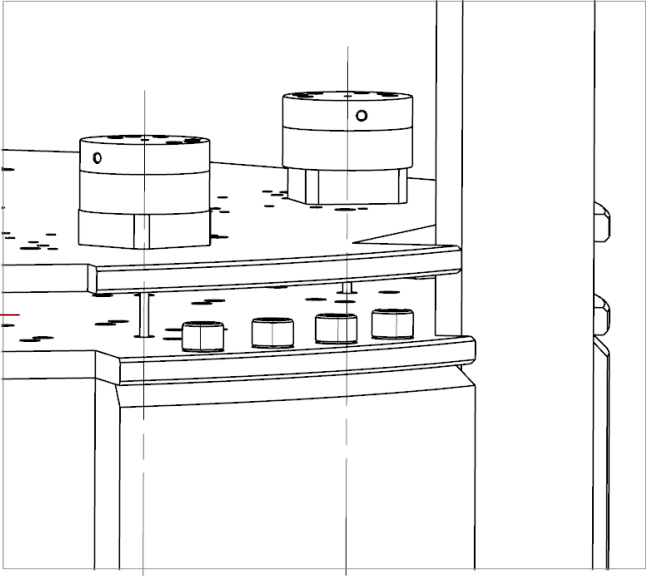
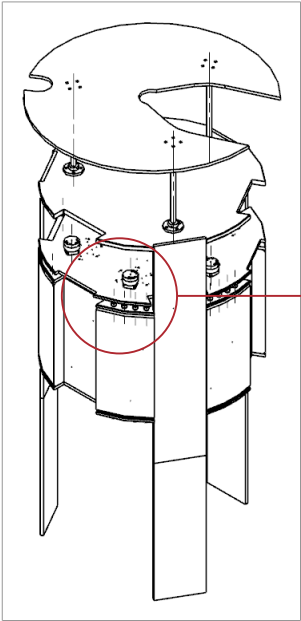


Tuning on ADMX

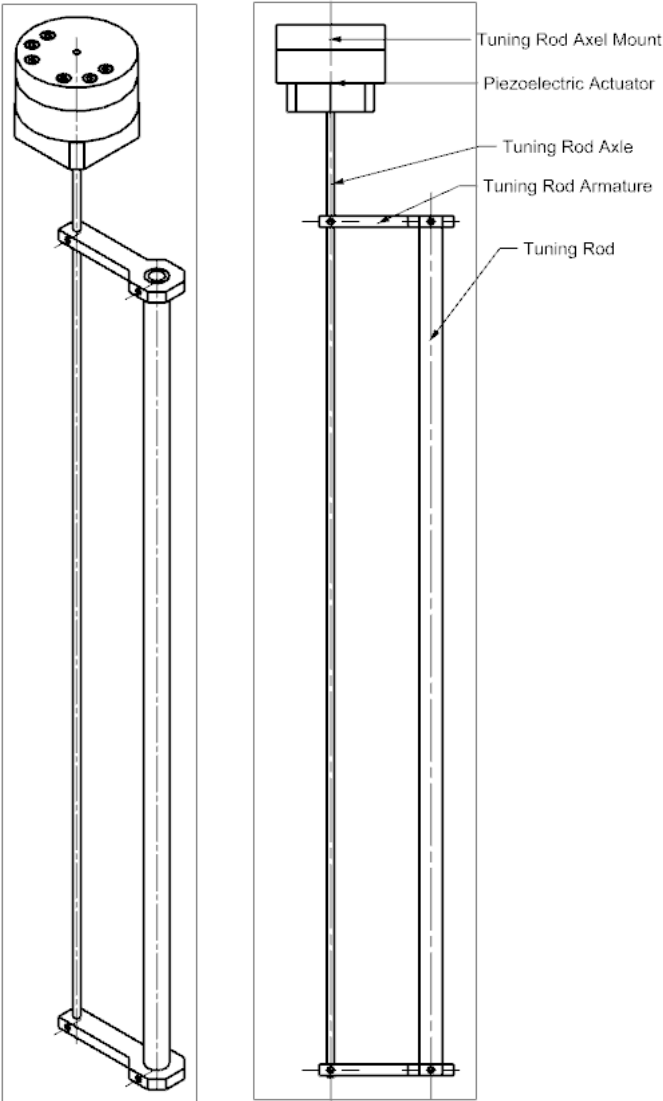
- Two tuning rods to tune cavity
- Linear tuning system for antennas
- What's the difference?



Tuning Rod Assembly

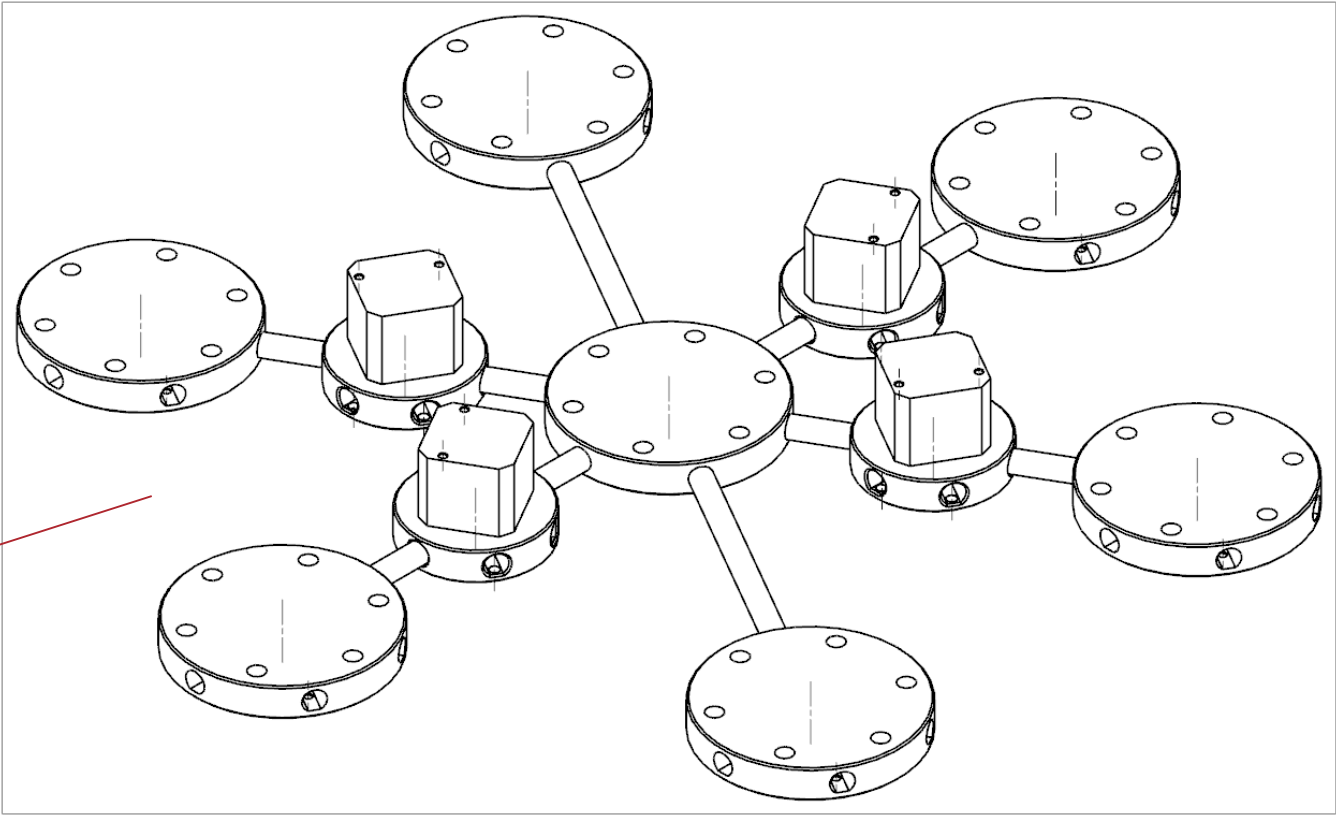
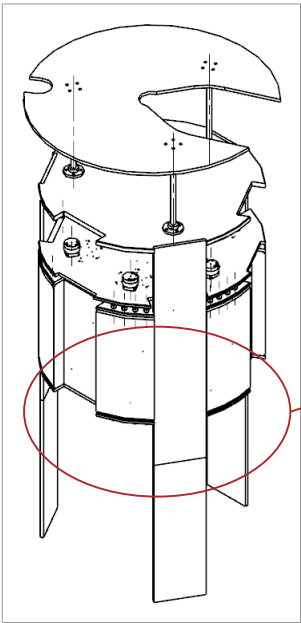


Tuning Rod Assembly

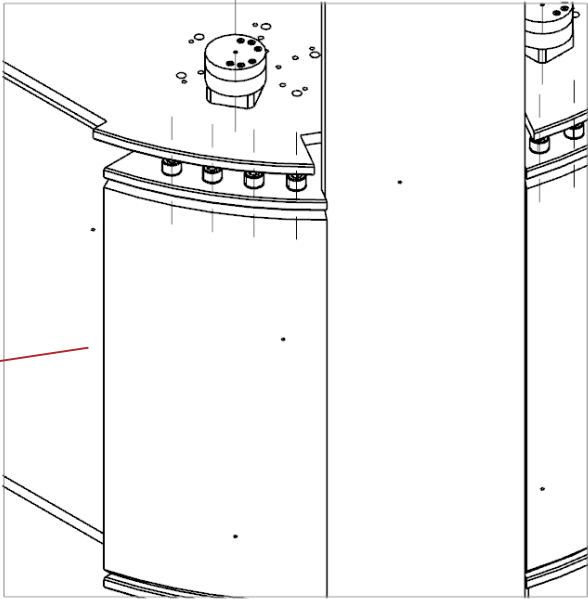
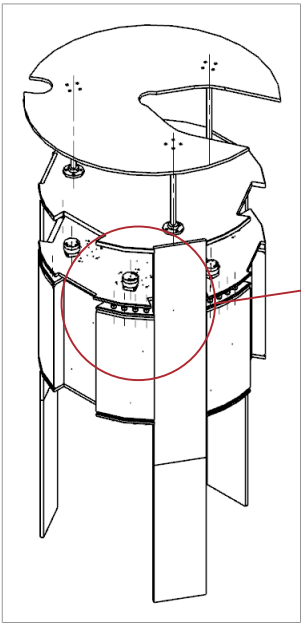


Attocube ANR101 Actuator

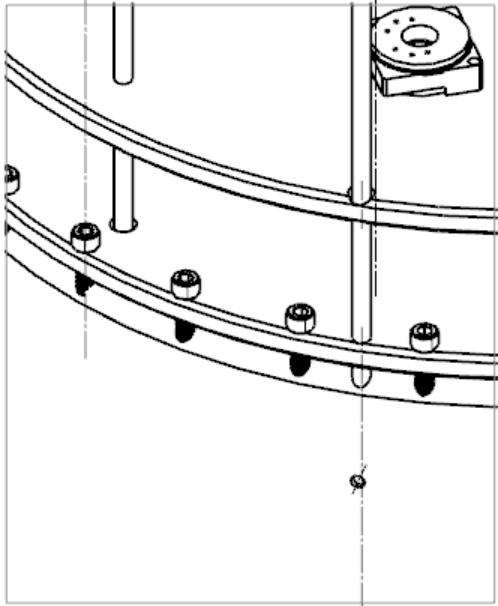
Linear Adjustment Assembly



Cold Fingers



New



Old

Future Plans

- Fine tune design
- Build prototype
- Collect data
- Implement multiple cavity design
- Find axions!

Acknowledgments

Thank you to:

- Quarknet (Chris Stoughton, Laura Thorpe, George Dzuricsko)
- Fermilab
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- Juan Takase

Acknowledgments

Big Thanks To: **Drake**
For design inspiration

