ADMX Status

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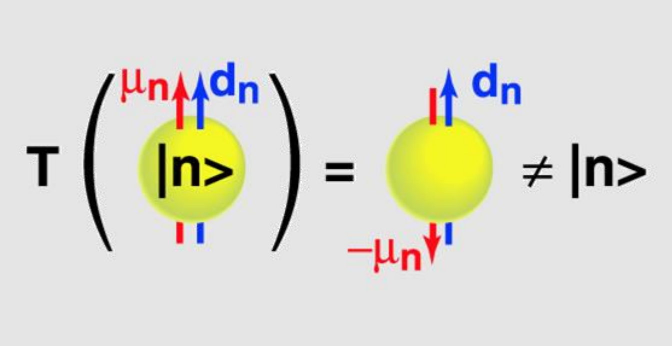
ADMX
AXION DARK MATTER EXPERIMENT

Strong CP Problem

- The Standard Model predicts QCD violates CP

$$\mathcal{L}_{QCD} = -\frac{1}{4} G^a_{\mu\nu} G^{a\mu\nu} + \frac{\theta g^2}{16\pi^2} G^a_{\mu\nu} \tilde{G}^{a\mu\nu} + \cdots$$

- Neutron electric dipole moment



- Experimental results have found no neutron electric dipole moment (PRL 97 131801)

$|d_n| < 2.9 \times 10^{-26}$ e-cm ⟹ $|\theta_{QCD}| < 10^{-9}$

Peccei–Quinn Solution

Peccei and Quinn

hidden broken U(1) symmetry (PRL 38 1440)

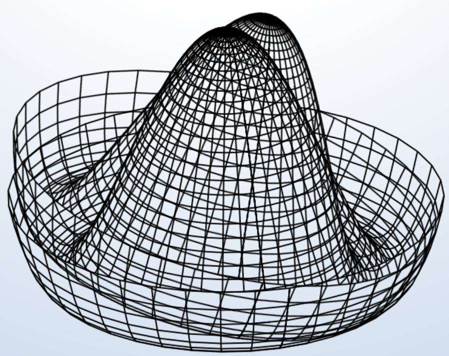
$$\mathcal{L} = -\frac{1}{4} G^{a}_{\mu\nu} G^{a\mu\nu} + |\bar{\theta}| \frac{g^2}{16\pi^2} G^{a}_{\mu\nu} \tilde{G}^{a\mu\nu} + \cdots$$

$$\mathcal{L}_{eff} = \mathcal{L}_{QCD} - \frac{1}{4} G^{a}_{\mu\nu} G^{a\mu\nu} + \left(\bar{\theta} + \frac{a}{f_{PQ}} \xi\right) \frac{g^2}{16\pi^2} G^{a}_{\mu\nu} \tilde{G}^{a\mu\nu} + \cdots$$

Weinberg and Wilczek

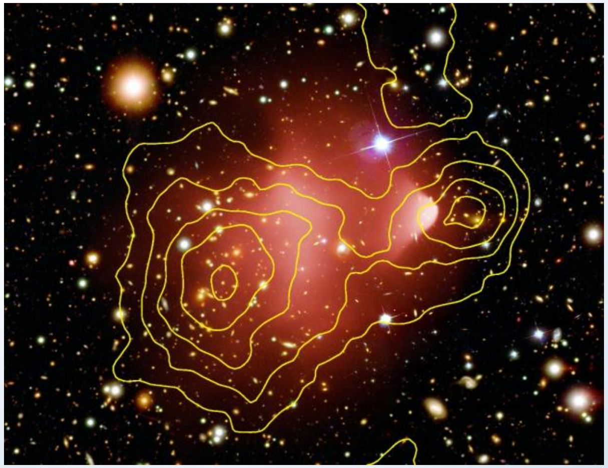
pseudo-Nambu Goldstone boson

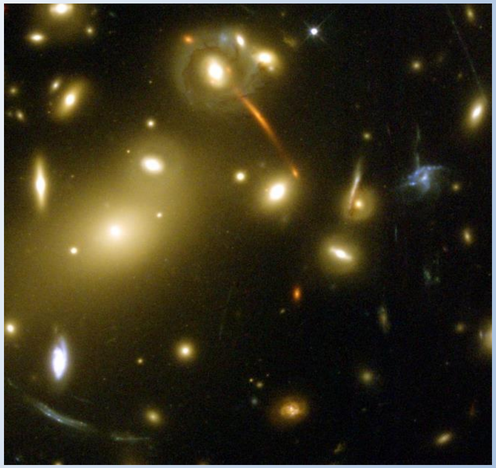
(PRL 40 223 & PRL 40 279)



Axion Dark Matter Candidate

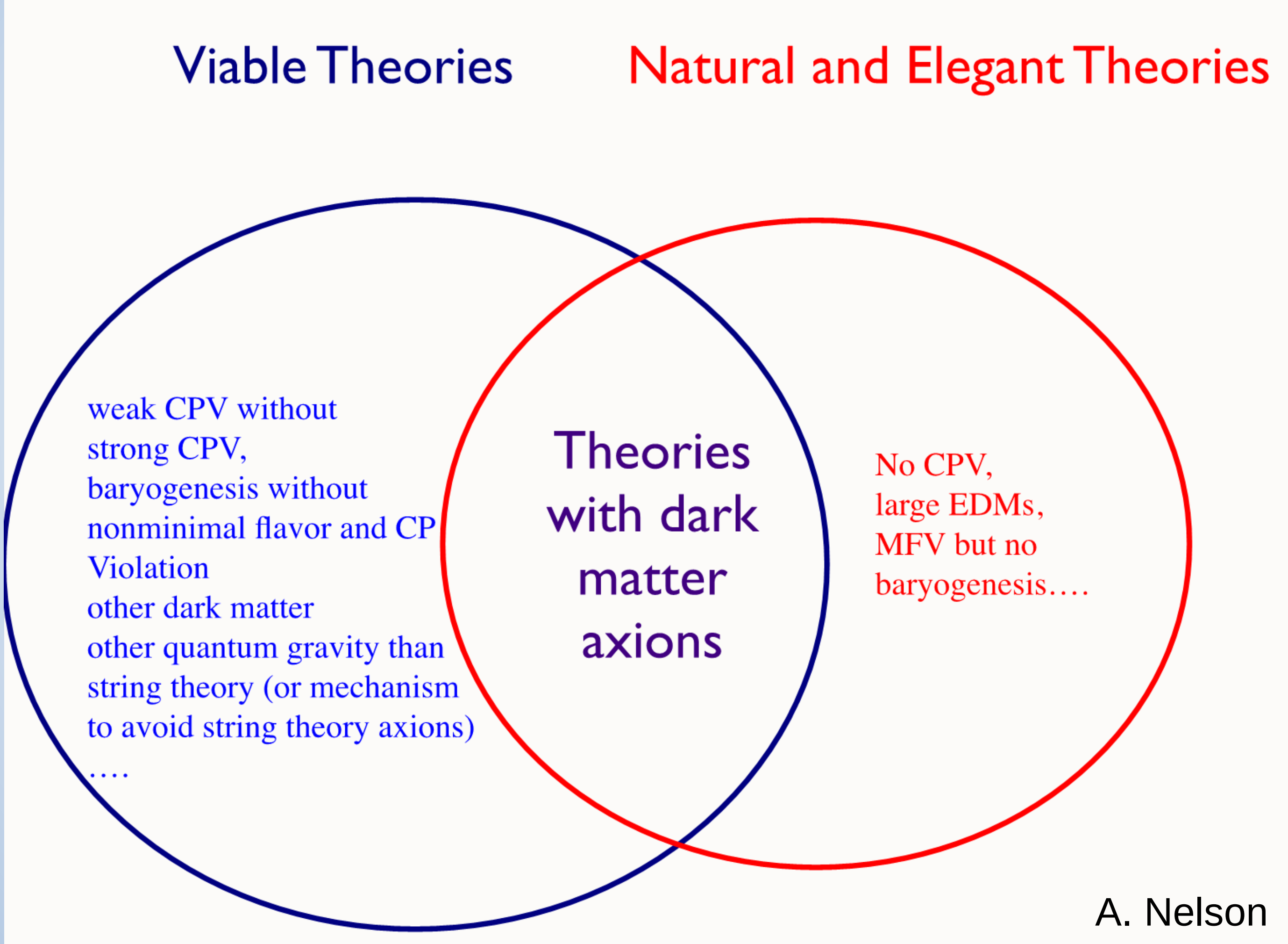
- Naturally meets the "requirements" of dark matter (PRD 86 010001)
  - feeble interactions with normal matter and radiation
  - strong gravitational interactions
  - cold
  - long-lived
  - abundant





- Elegant solution
  - no fine-tuning
  - mass bound
  - no dark matter specific theory added

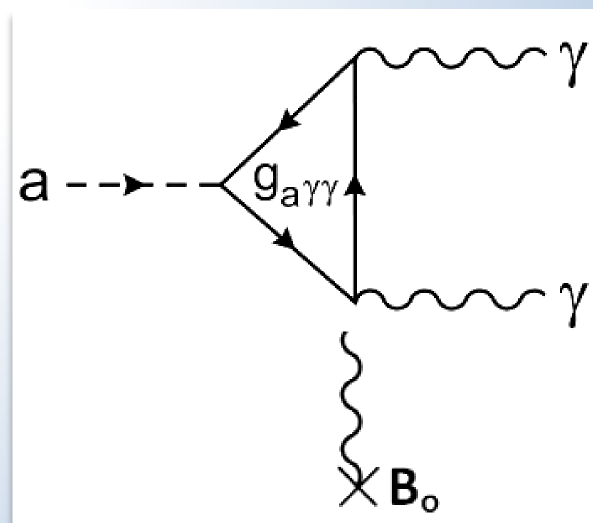
Axion Dark Matter Theory



Axion Detection

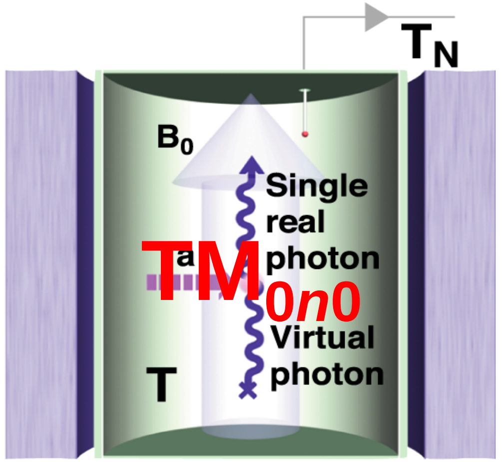
- The axion couples very weakly to normal particles.
  - μeV-mass axions would live around 10^{50} seconds.
- Lifetime is greatly decrease in static magnetic field via the inverse Primakoff effect. (PRL 51 1415)

$$\mathcal{L}_{a\gamma\gamma} = g_{a\gamma\gamma}\, a\, \boldsymbol{E} \cdot \boldsymbol{B}_{\mathbf{0}}$$



Microwave Cavity (Haloscope) Detectors

Primakoff Conversion

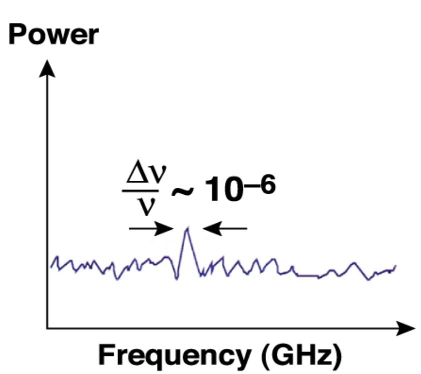


- The conversion is resonant, i.e. the frequency must equal the mass + K. E.
- The total system noise temperature $T_S = T + T_N$ is the critical factor

"Fixed" by magnet bore

The search speed is quadratic in 1/Ts

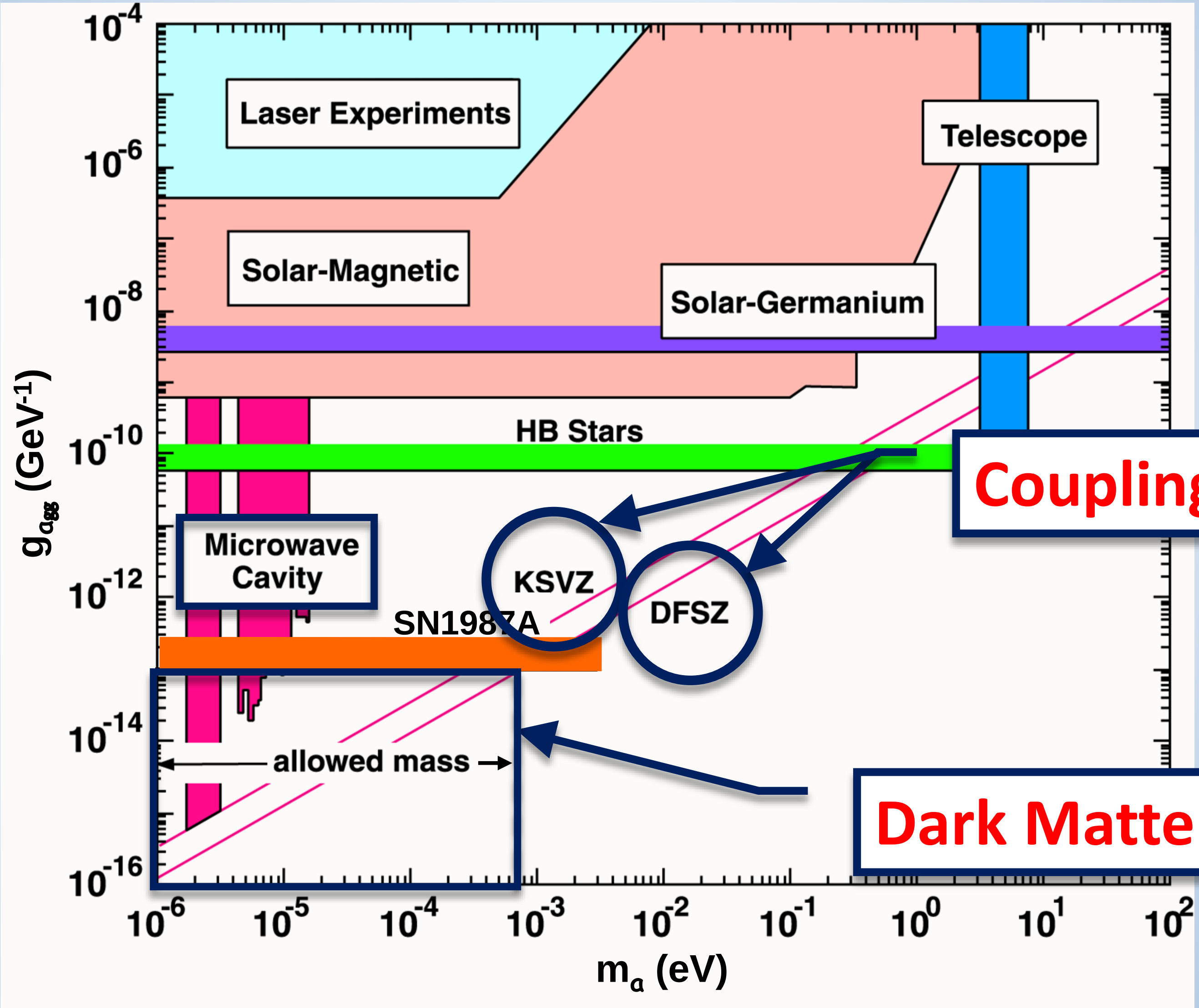
Signal



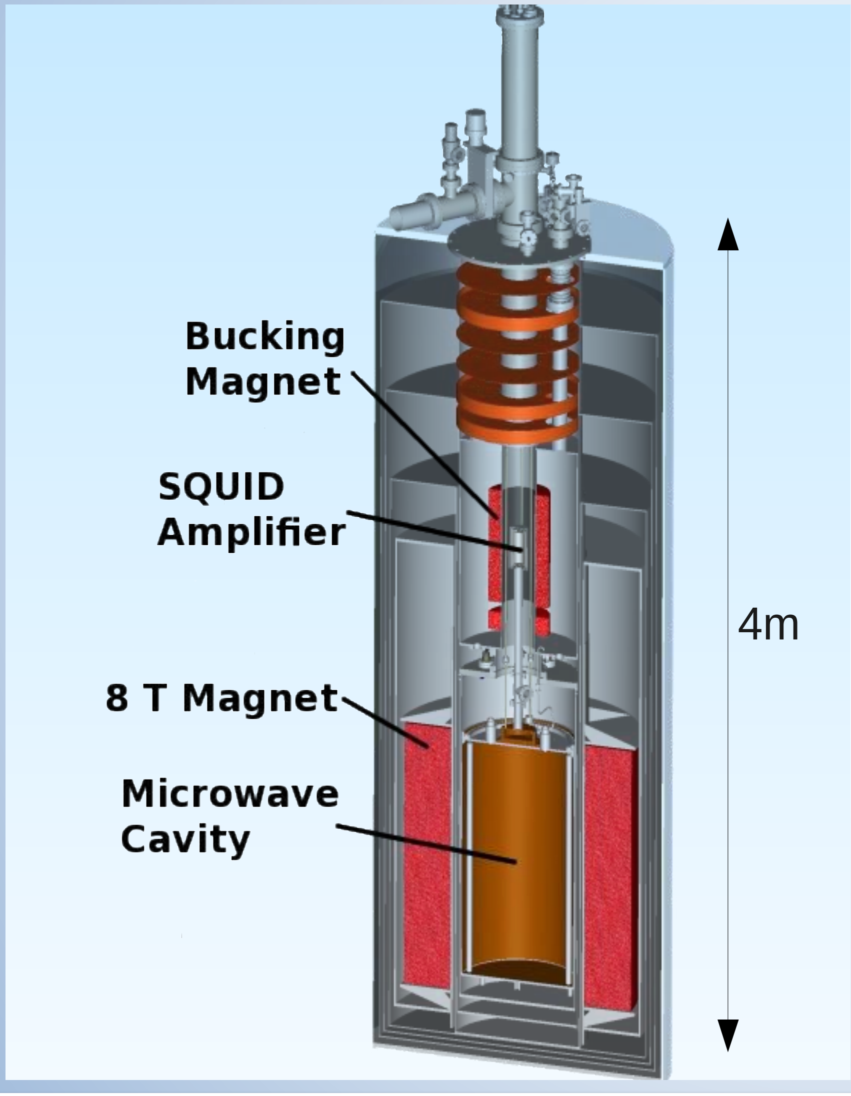
Scaling Laws

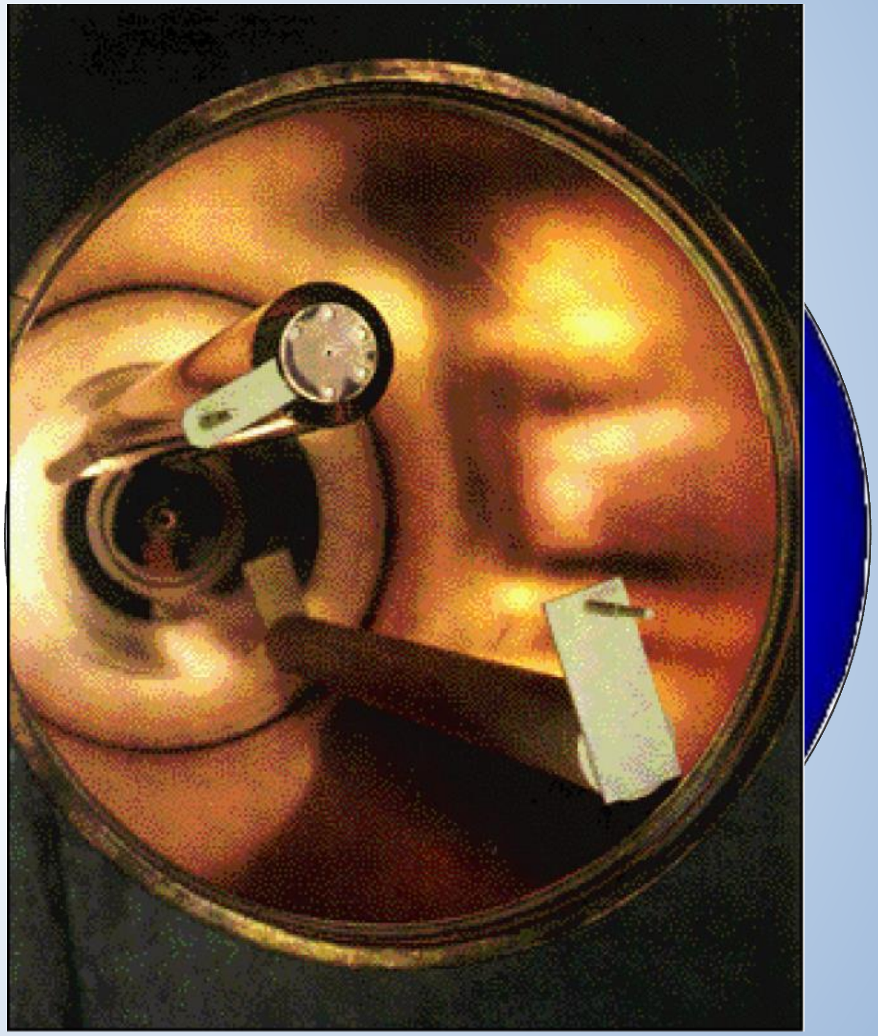
$\frac{d\nu}{dt} \propto B^4 V^2 \cdot \frac{1}{T_S^2}$	$g_\gamma^2 \propto \left(B^2 V \cdot \frac{1}{T_S}\right)^{-1}$
For fixed model g^2	For fixed scan rate $\frac{d\nu}{dt}$

Axion Detector Results

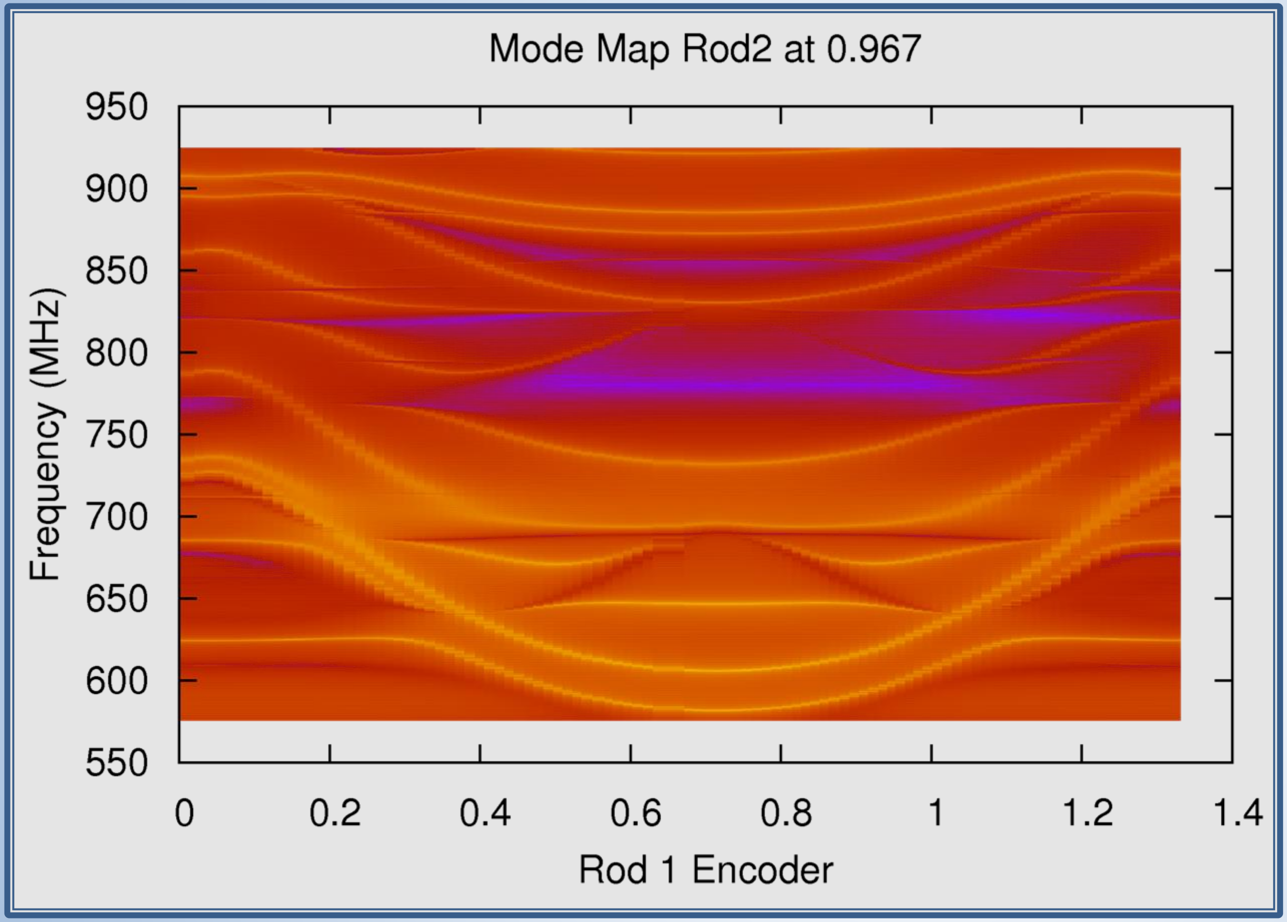


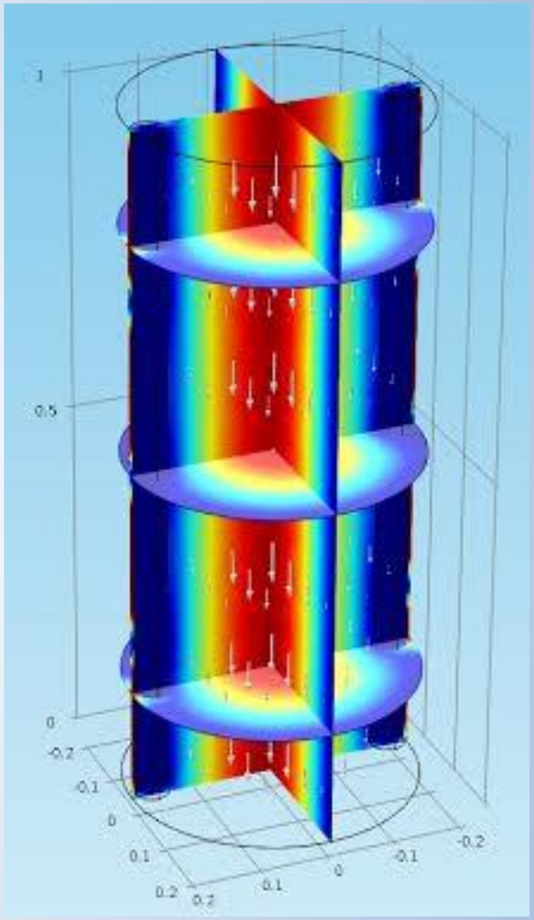
Axion Dark Matter eXperiment (ADMX)





Cavity Tuning

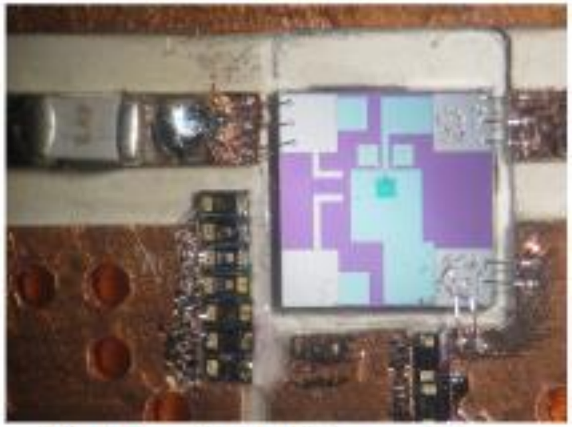




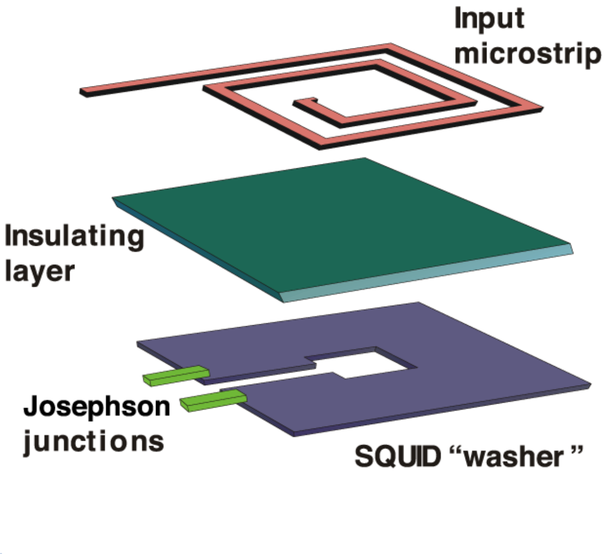
Data taking cadence: Tune rods, measure frequency, acquire power spectrum, repeat.

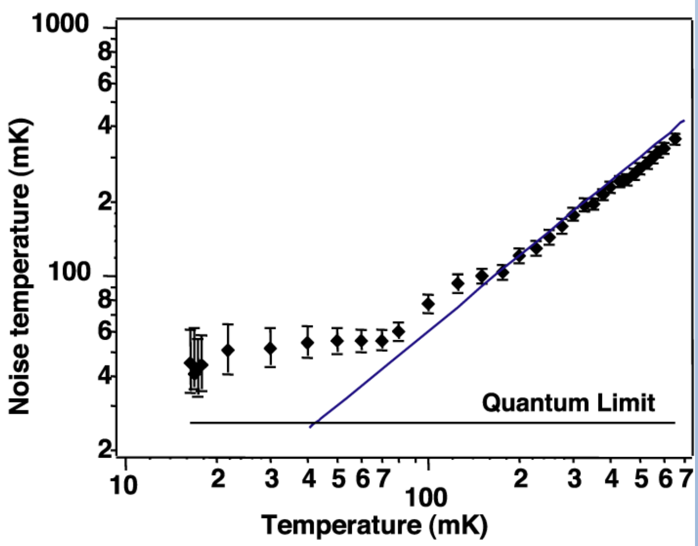
SQUID-based amplifier

- SQUIDs have been measured with T_N ~ 50 mK
  - Near quantum–limited noise
- ~15-20 dB gain

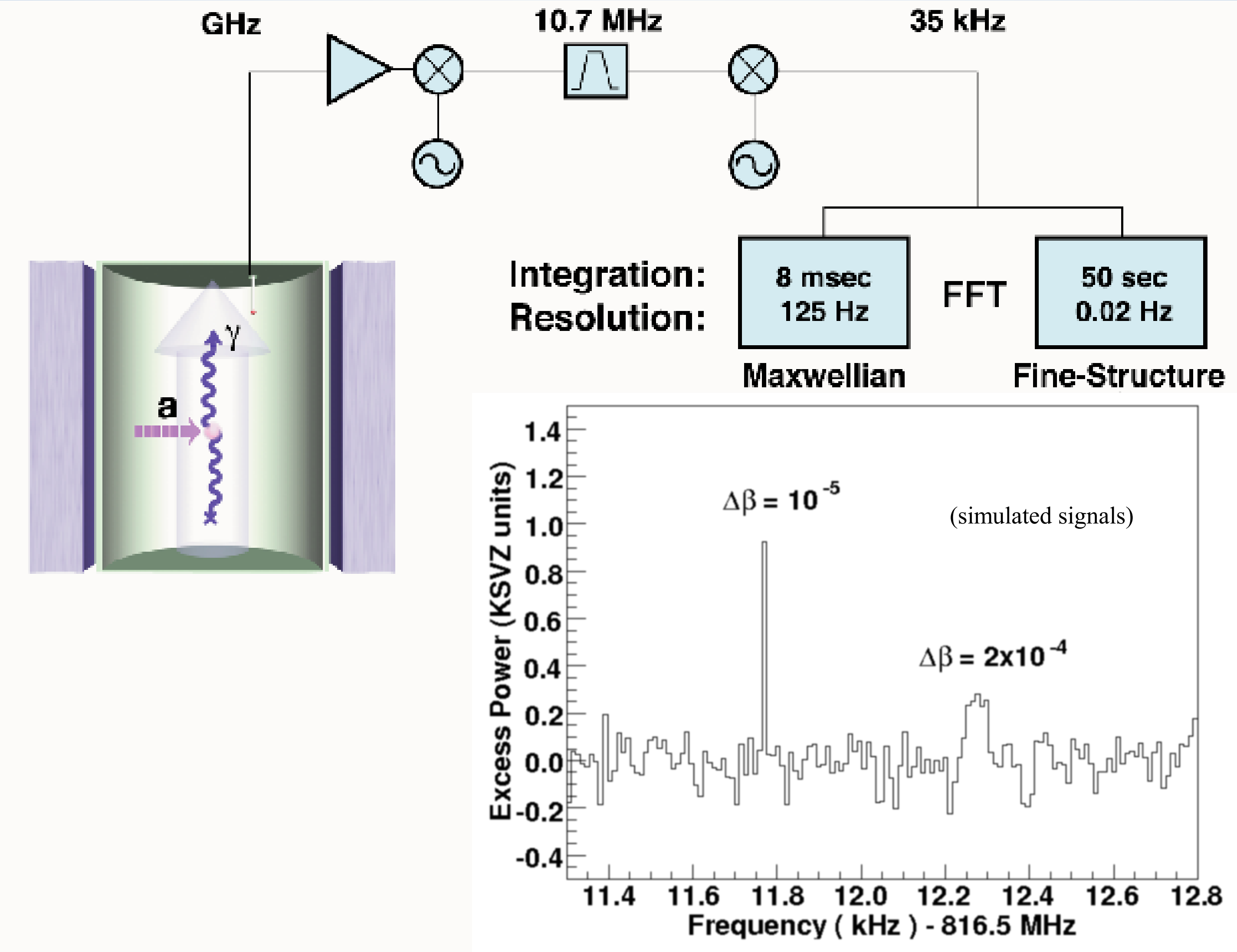


Niobium SQUID amplifier

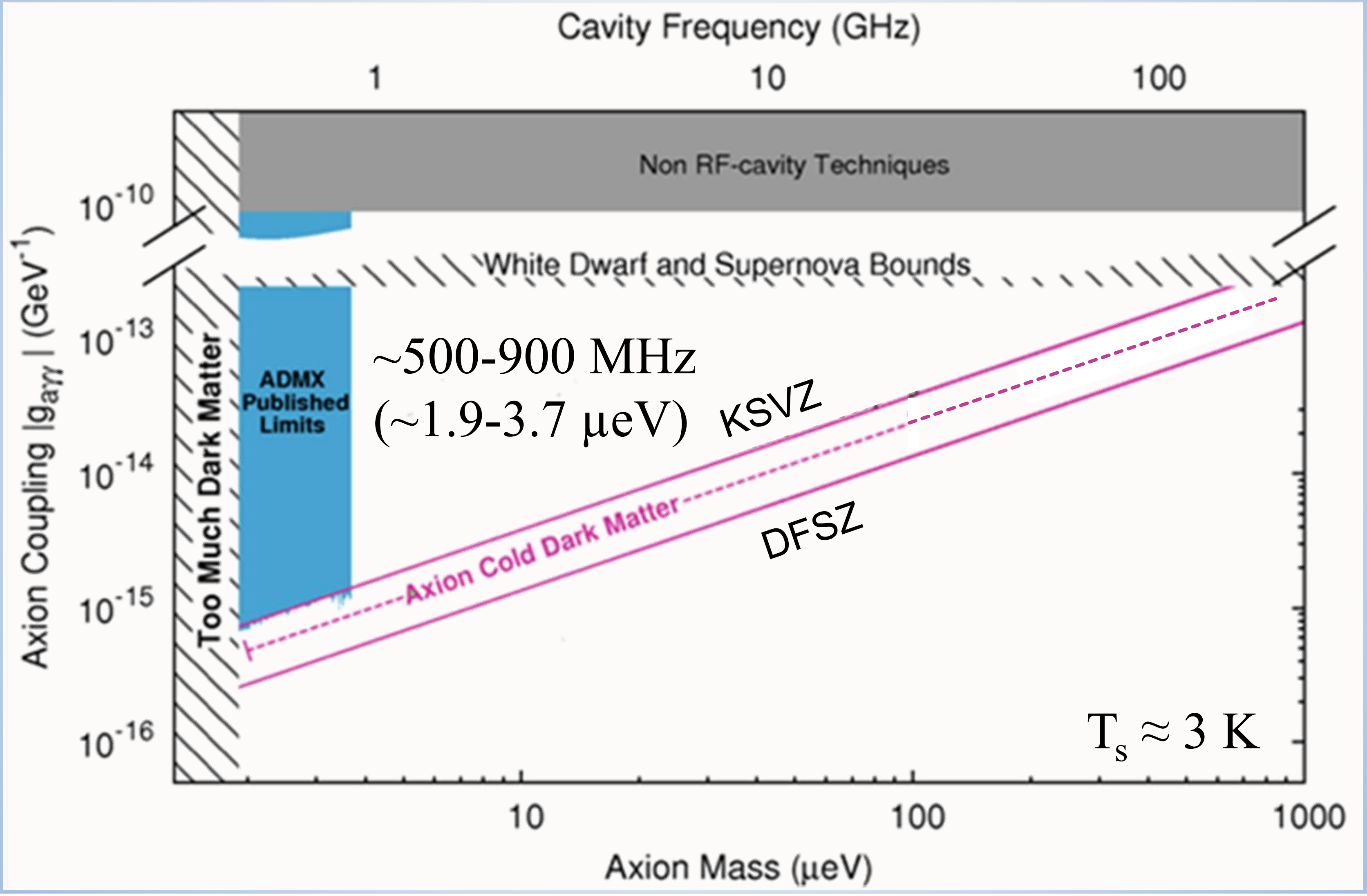




Receiver Chain

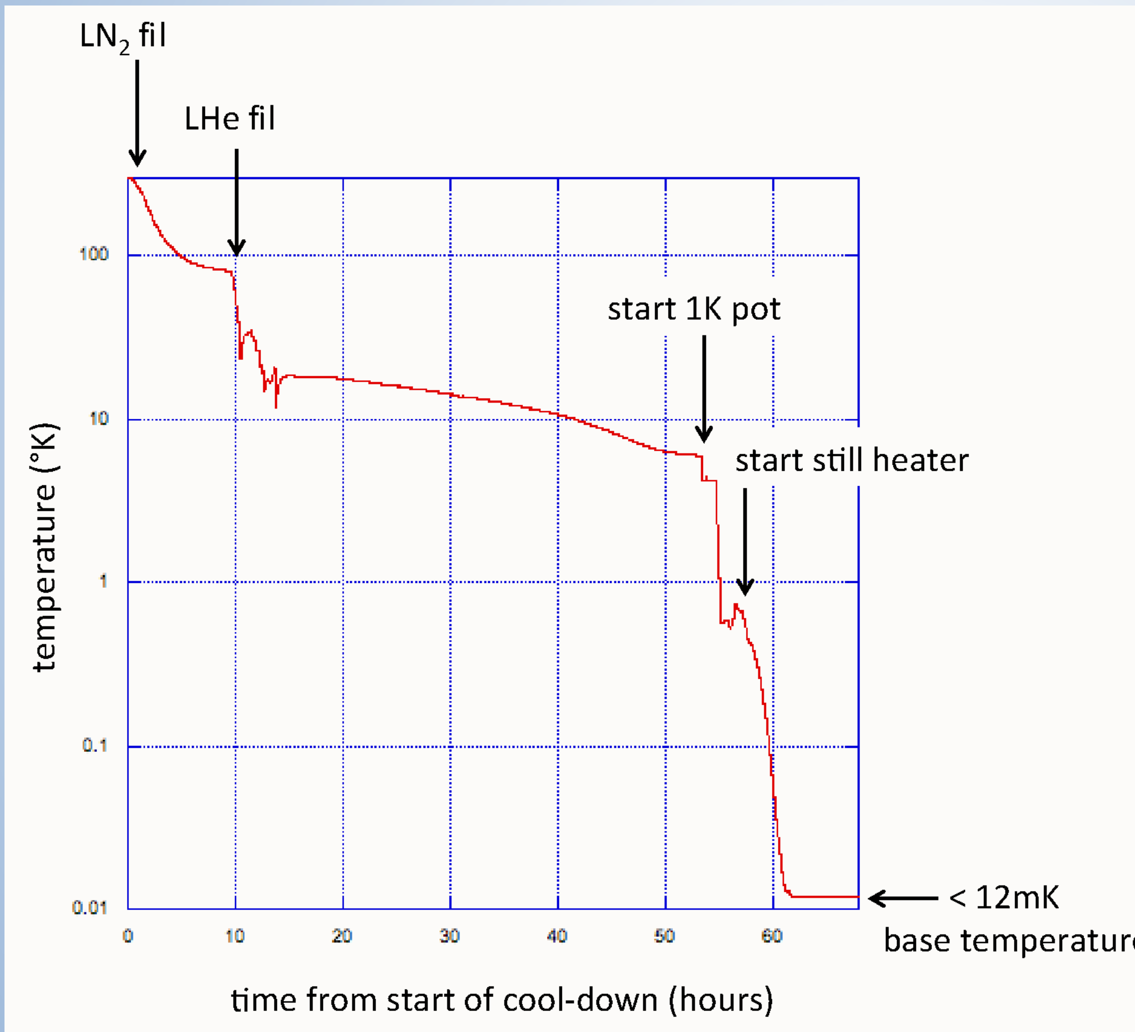


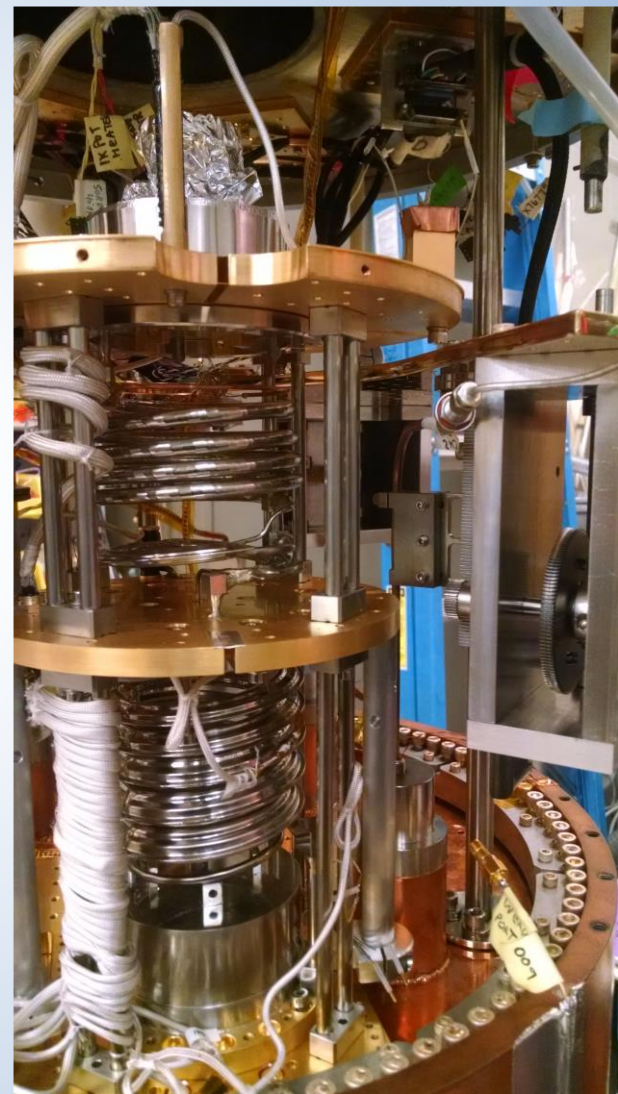
ADMX Published Limits



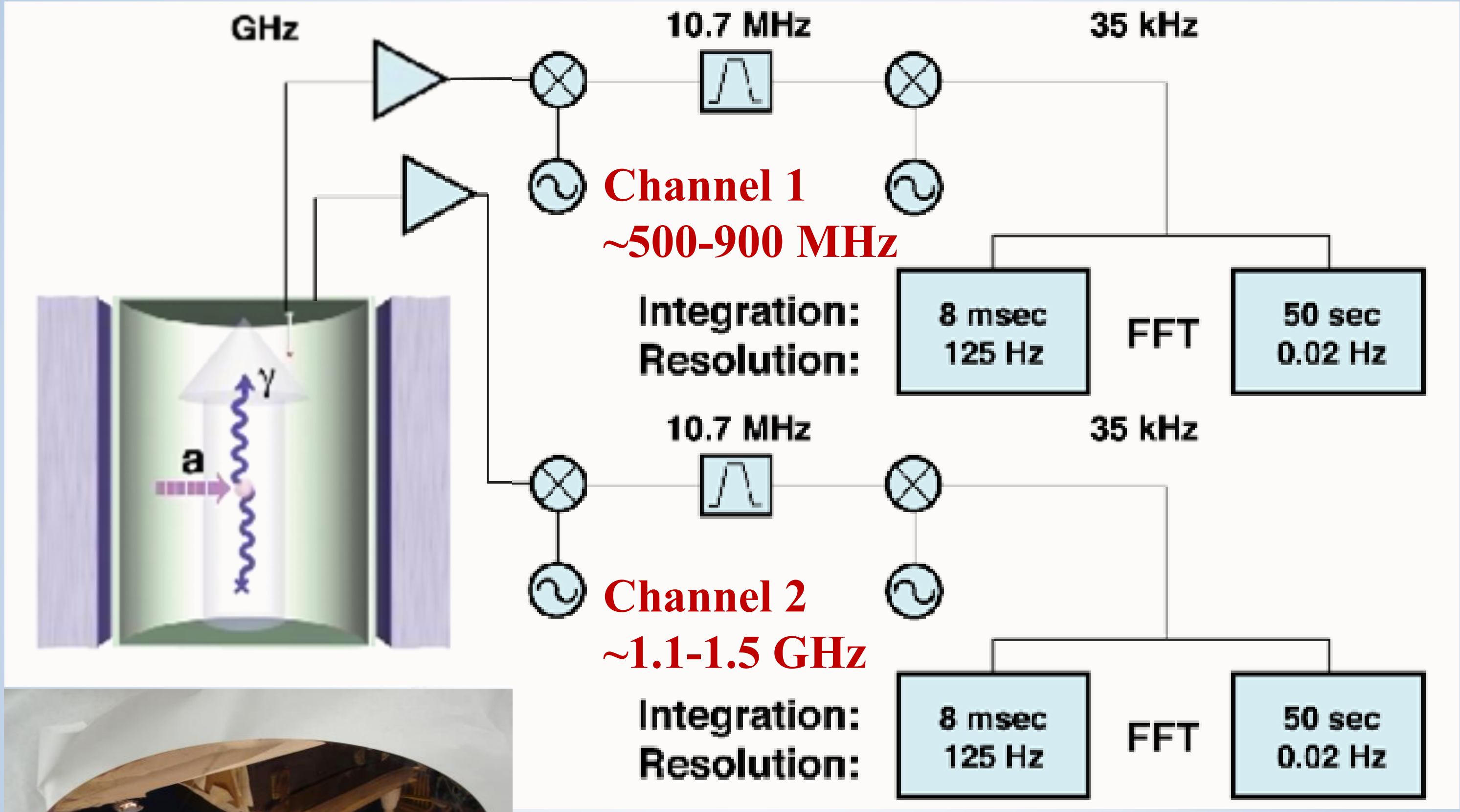
Current Upgrade: Dilution Refrigerator

T ≈ 200 mK (target 100 mK)





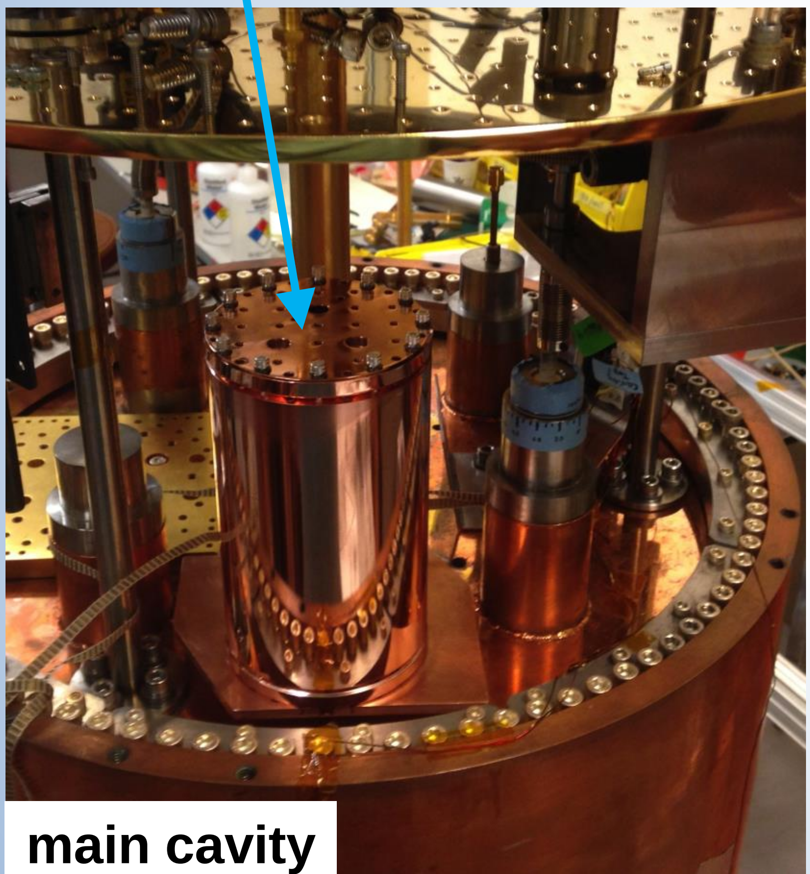
Current Upgrade: Multi-channel Cavity

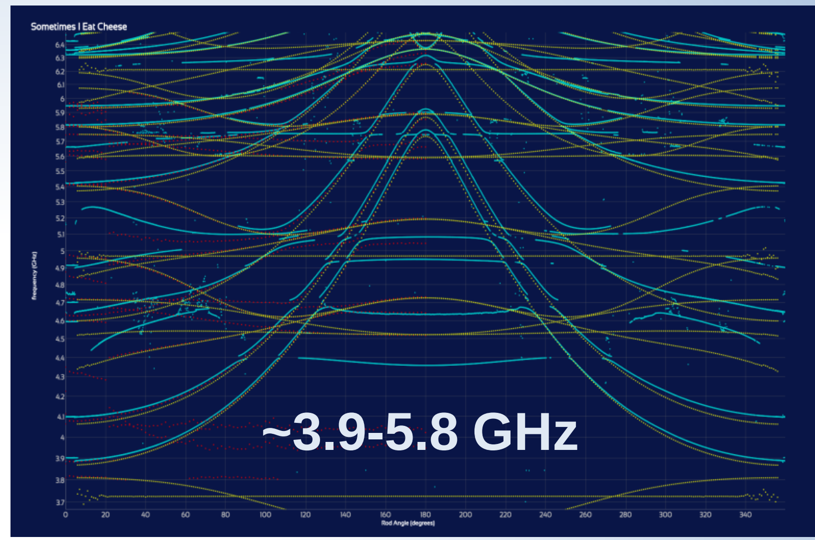


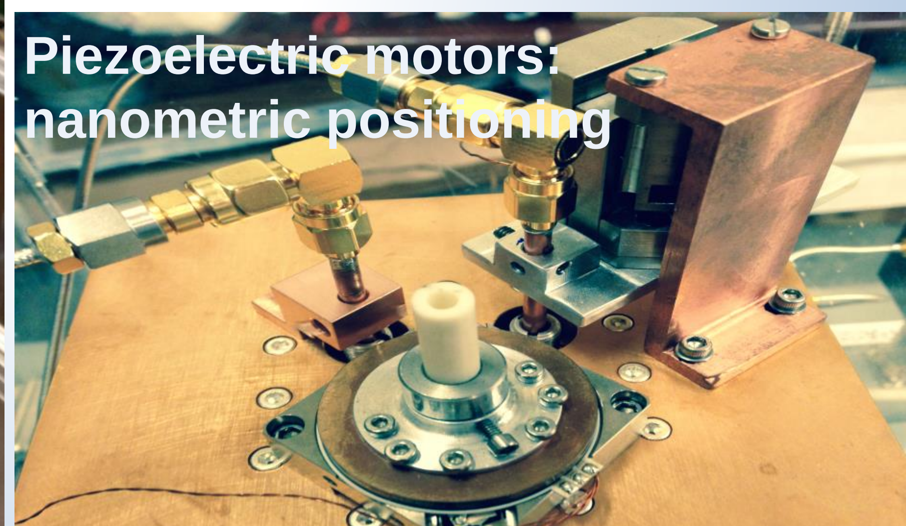
Scan next higher coupled mode: lower axion coupling

Current Upgrade: “Sidecar” Cavity

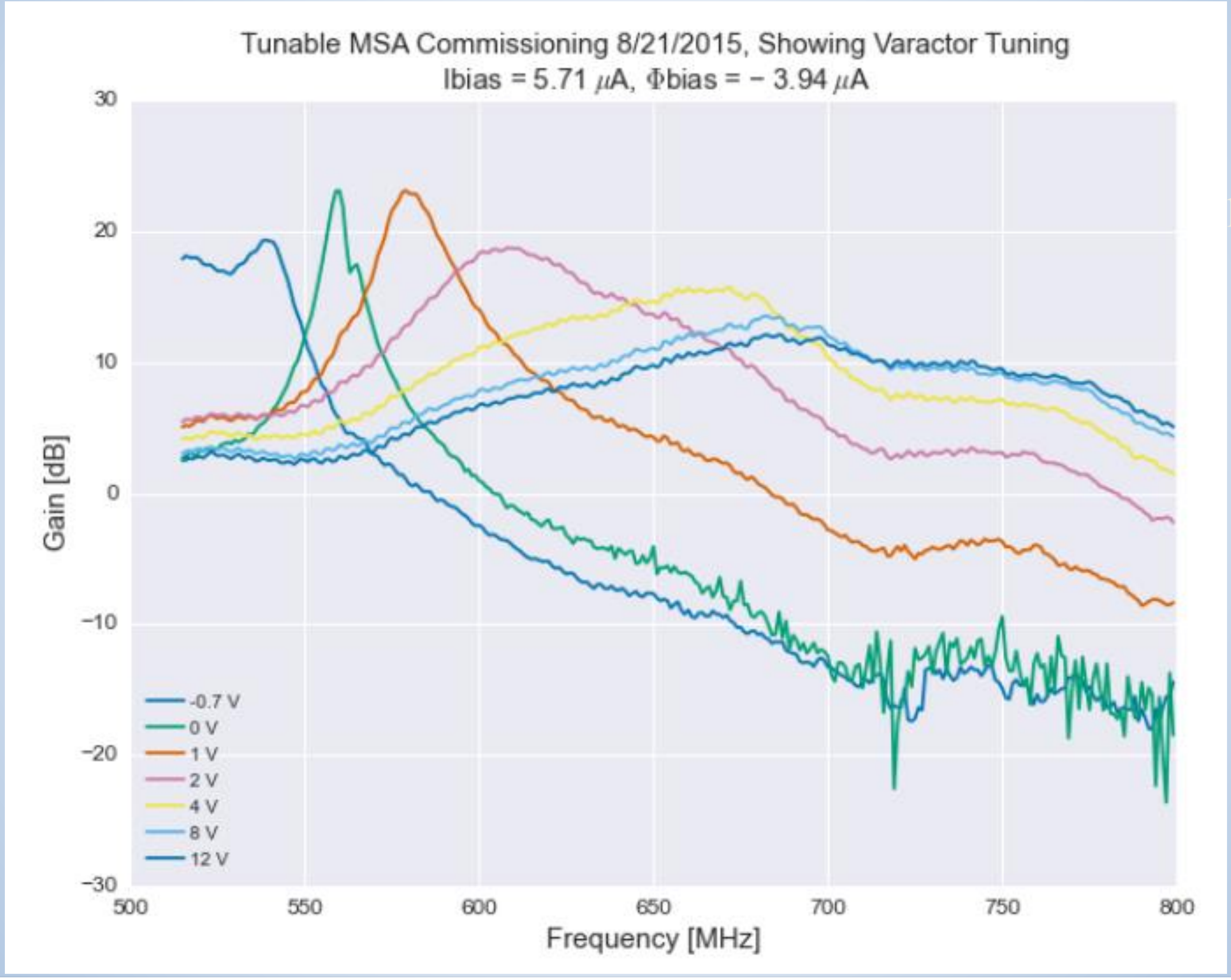
“sidecar” cavity







Current Upgrade: Tunable Amplifiers



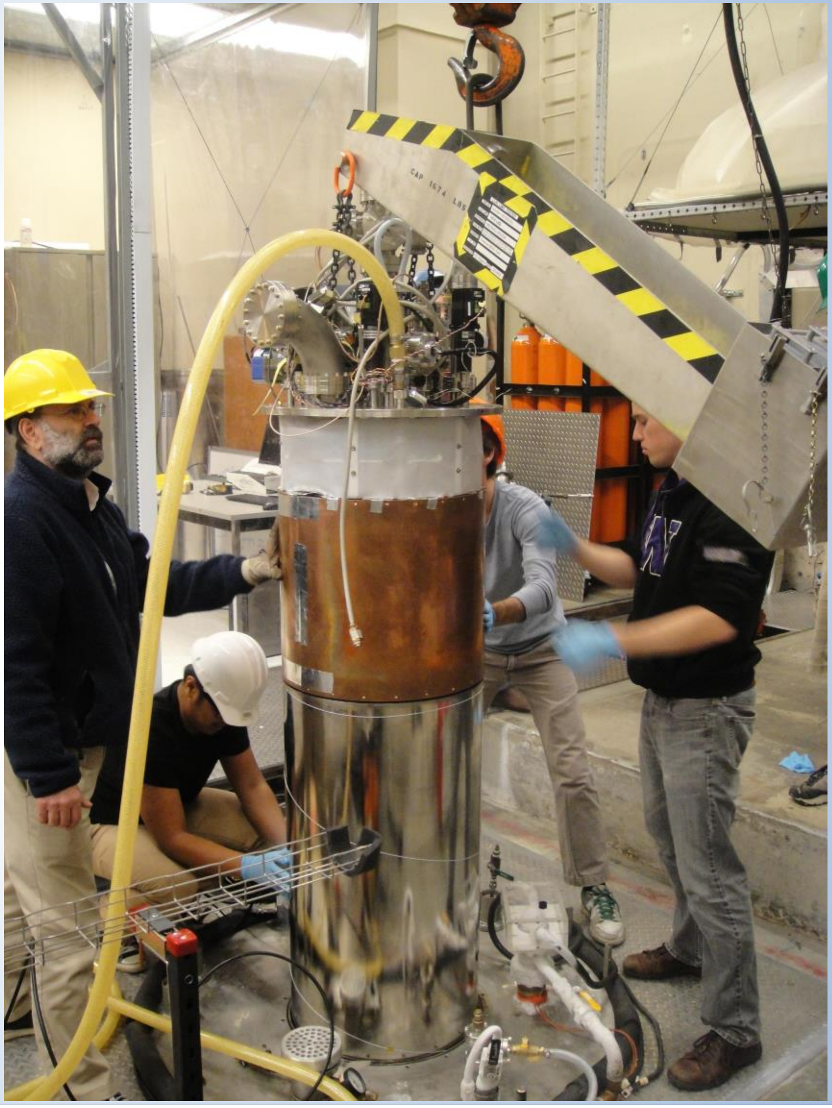
led

UF UNIVERSITY of FLORIDA

ADMX AXION DARK MATTER EXPERIMENT

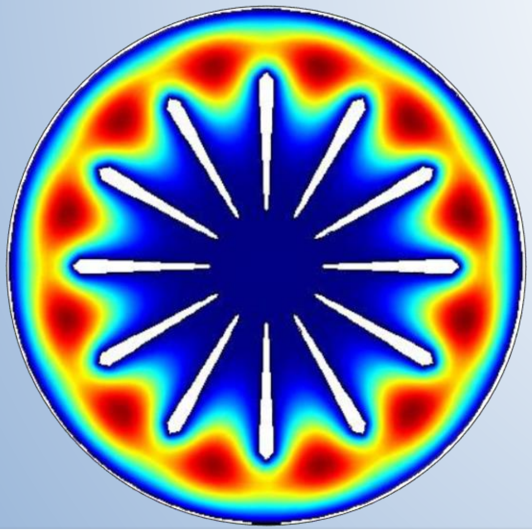
Current Status

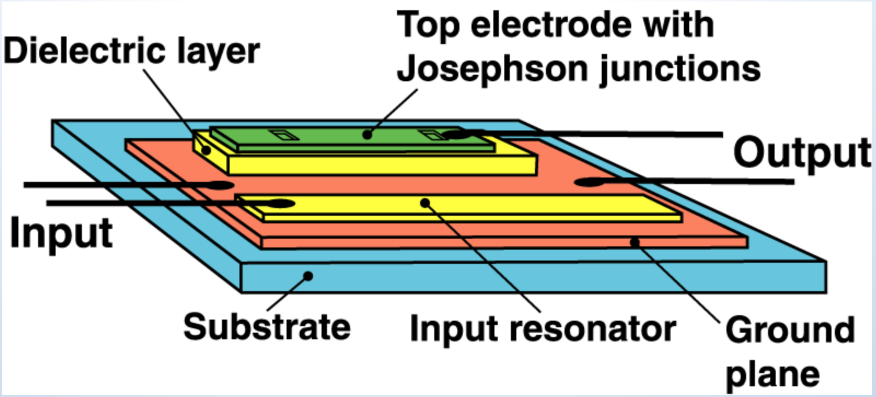
- Dil. fridge installed and operational
- 3 search channels operational and verified
- Electronics in final commissioning phase
- Science data taking will begin in August!!
  - Most sensitive detector
  - New frequency searches



ADMX Gen 2

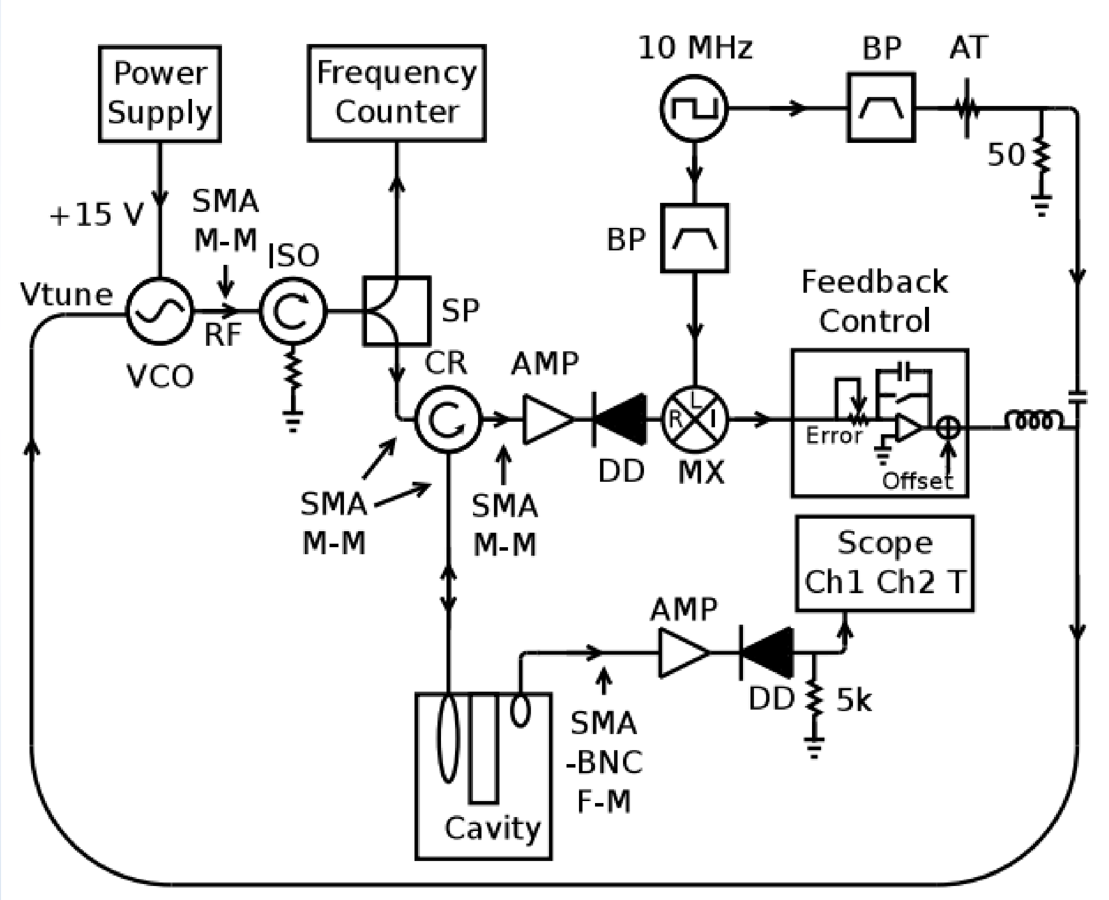
- Search for dark matter axions down to DFSZ coupling in frequency range of ~1-10 GHz
  - New microwave cavity technology research
  - New electronics development
  - Upgraded magnet



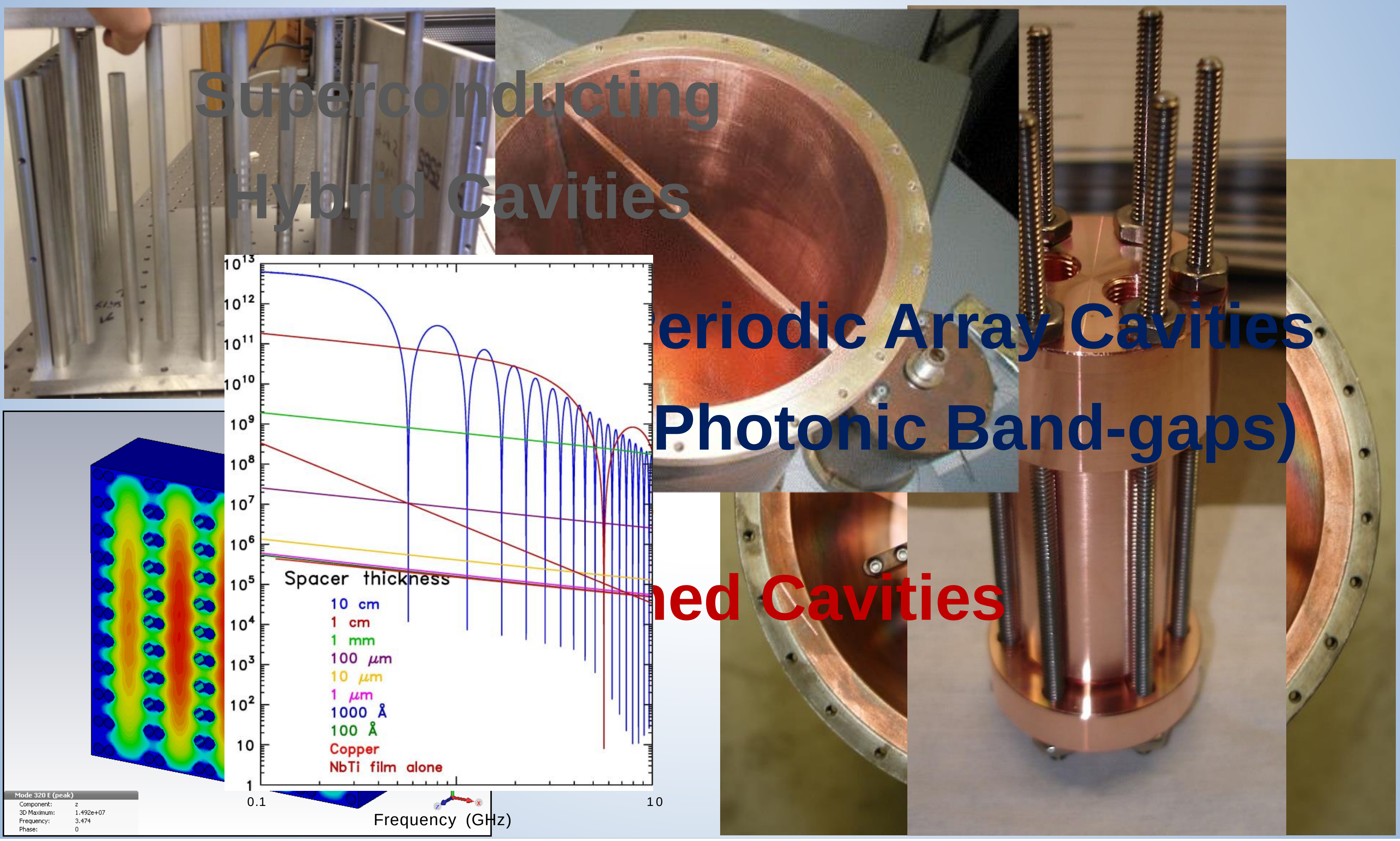


Current R&D: Multi-cavity Searches

Pound locking system

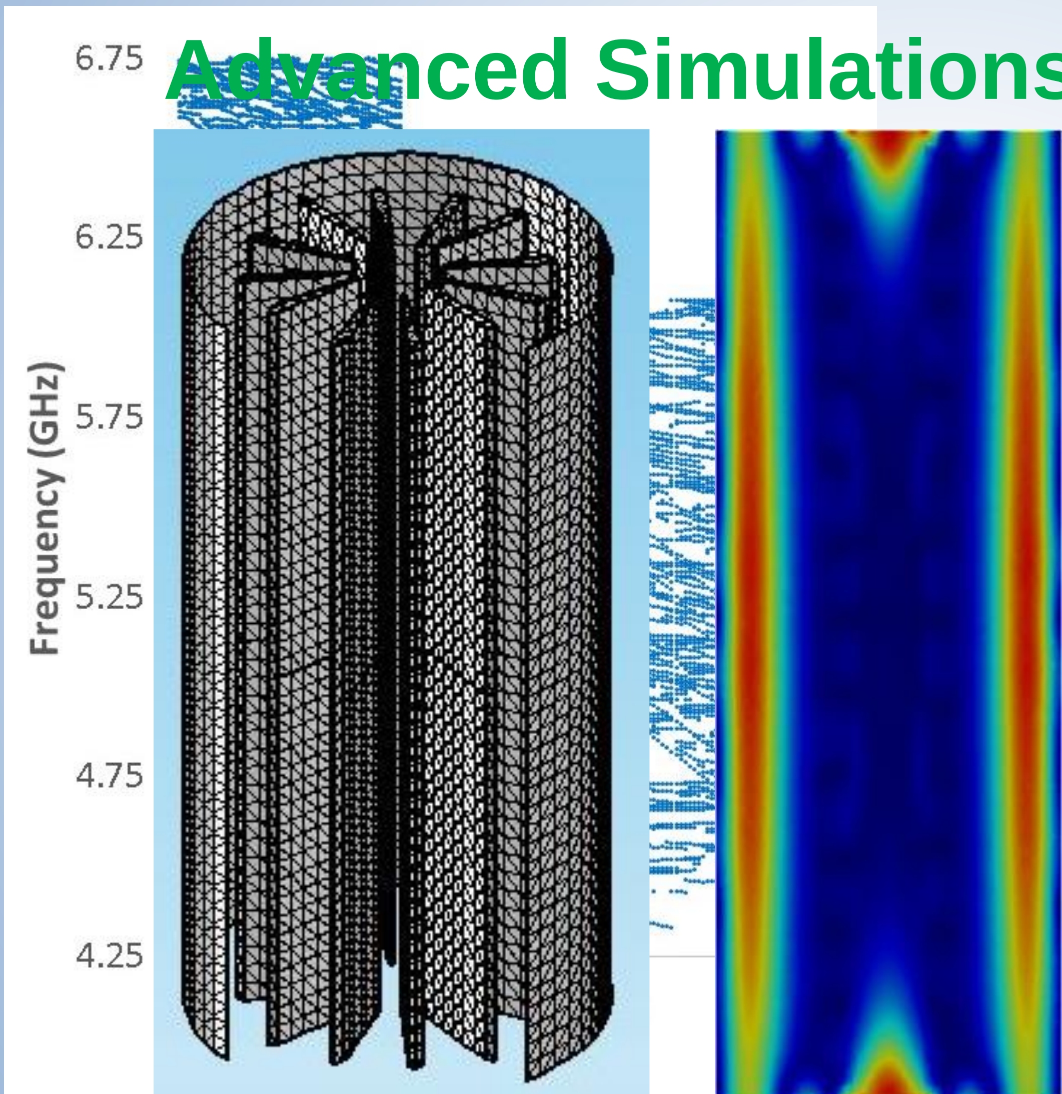


Current R&D: Exotic Cavity Development

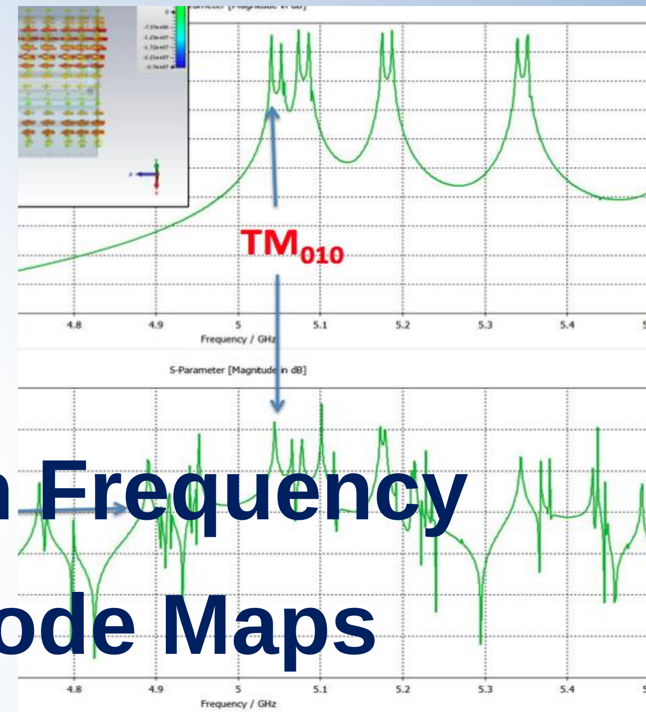


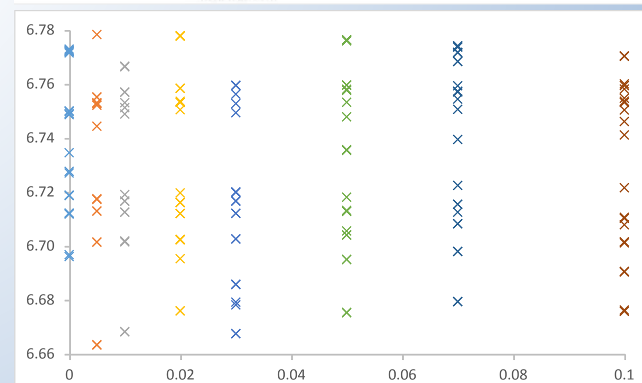
Current R&D: Mode Map and Simulation

Advanced Simulations

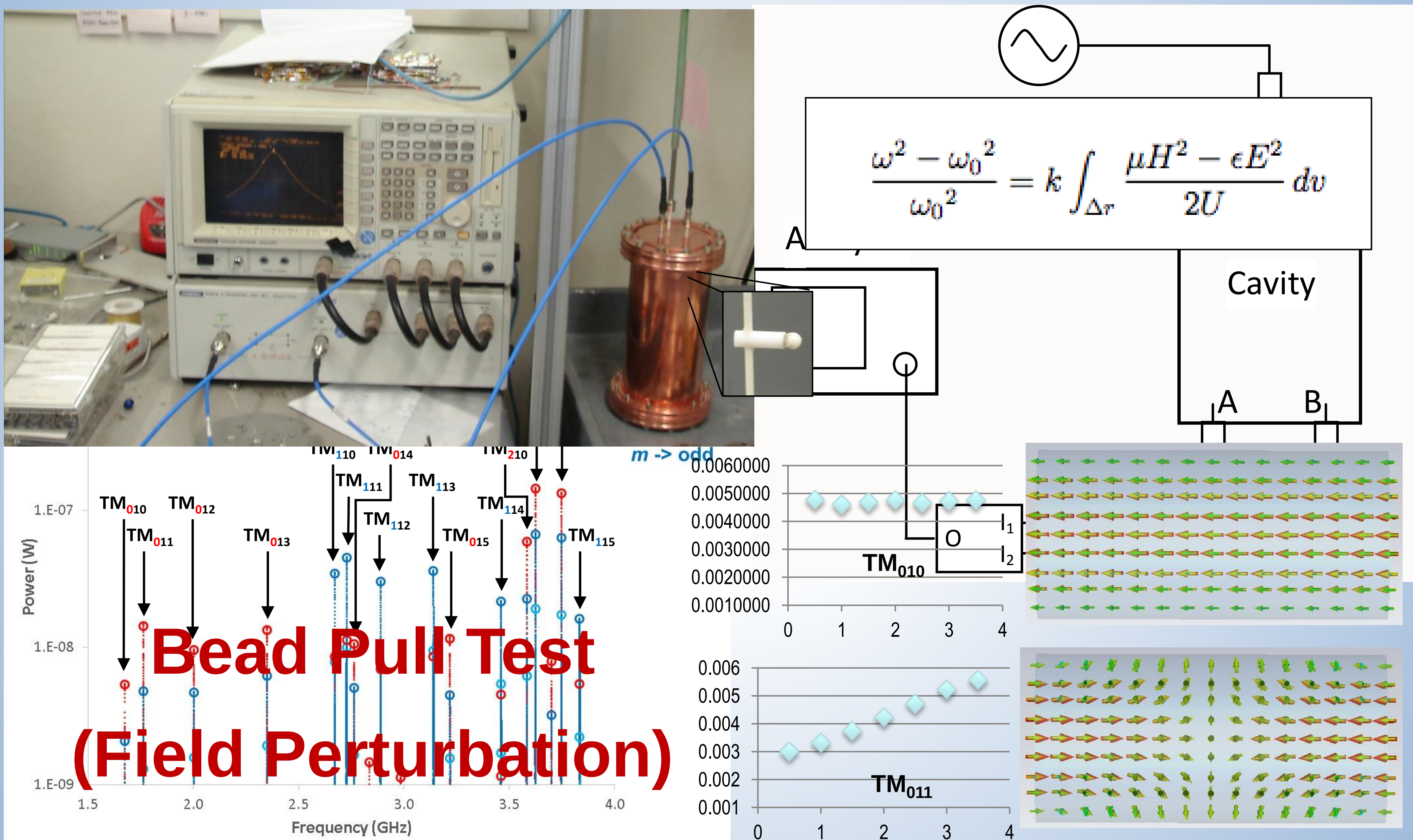


High Frequency Mode Maps



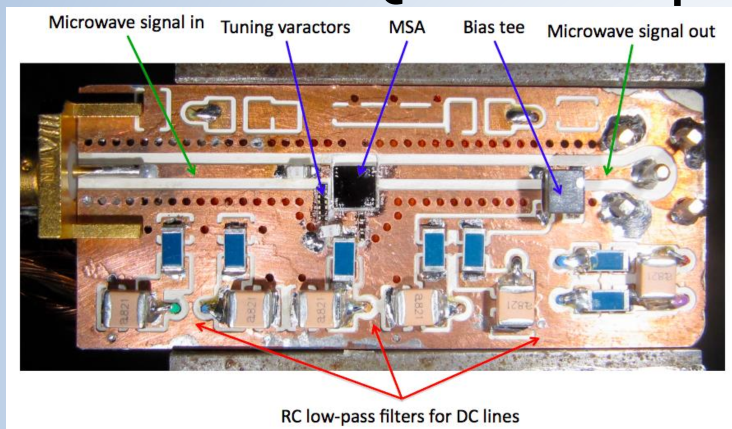


Current R&D: Mode Identification

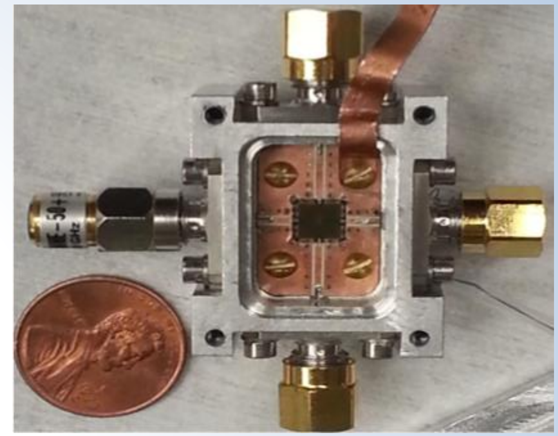


Current R&D: Electronics and Magnet

Tunable SQUID Amps

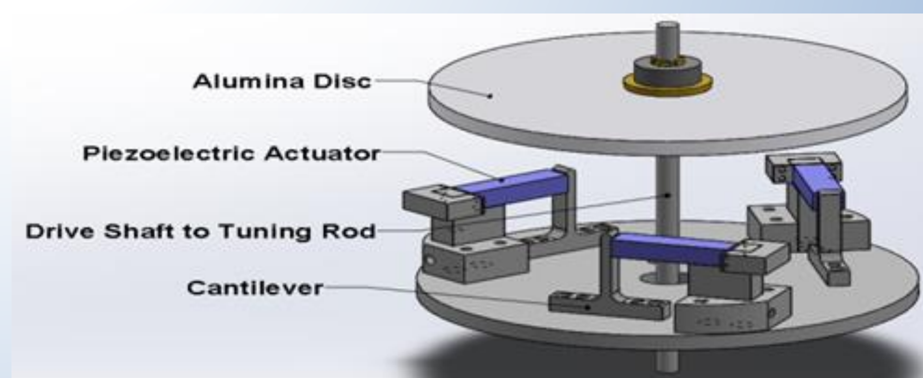


JPA Advancements



Stronger Magnets

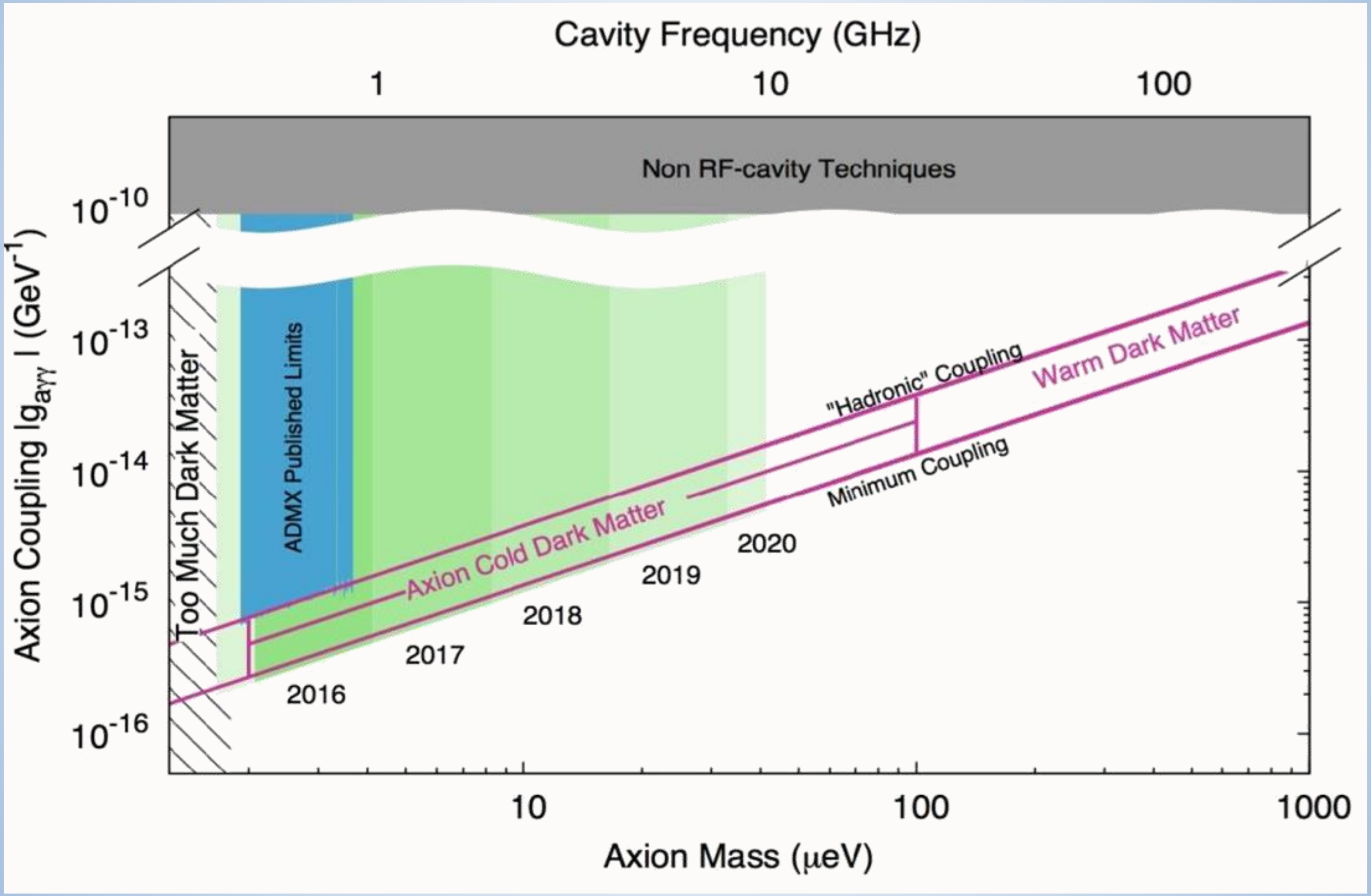
Piezoelectric Drive



Gen 2 Cavity Baseline

- 1-2 GHz: 4 frequency-locked cavities
  - R ≈ 8 cm
- 2-4 GHz: 16 frequency-locked cavities
  - R ≈ 4 cm
- 4-6 GHz: 32 frequency-locked cavities
  - R ≈ 3 cm
- 6-8 GHz: photonic band-gap (square) cavity
  - ~14 cm X 14 cm
- 8-10 GHz: photonic band-gap cavity
  - TBD

Projected Sensitivity



Conclusion

- ADMX is about to begin operating with the detector's greatest sensitivity to axion dark matter in a plausible mass range.
  - New mass/frequency ranges will be explored.
  - Significantly more discovery potential than previous dark matter axion searches.
- ADMX is rapidly advancing in technology to expand the detector's capabilities to explore higher mass regions with equivalent sensitivity.
  - Plan to search up to 1 decade in 5+ years.

ADMX Collaboration

- Collaboration Team
  - University of Washington
  - University of Florida
  - University of California, Berkeley
  - Lawrence Livermore National Laboratory
  - Fermilab
  - Pacific Northwest National Laboratory
  - Los Alamos National Lab
  - National Radio Astronomy Observatory

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