The Axion Dark Matter eXperiment (ADMX): Overview & Recent Results

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UCLA Dark Matter 2018 symposium

Outline

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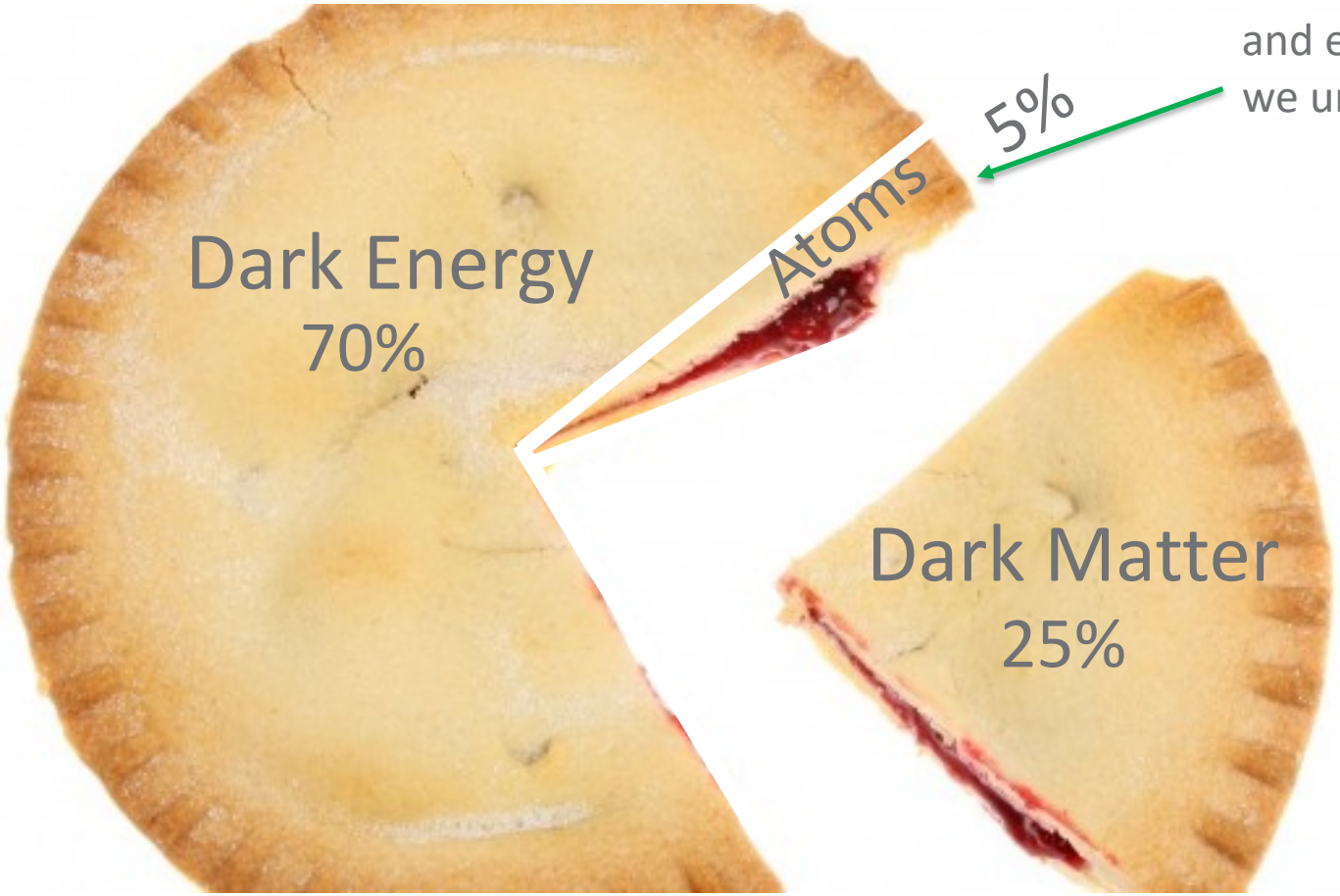
ADMX
AXION DARK MATTER EXPERIMENT

- Axions
- Axion Dark Matter eXperiment (ADMX) Overview
- 2017 Operations/Results
- The Future of ADMX

We have a dark matter problem



What does dark matter taste like?

WIMPS

Axions

Sterile Neutrinos

Hidden Sector Pie

What's so great about Axions?

A Few Axion Properties

Cosmological Abundance

$$\Omega_a \sim \left(\frac{5\mu eV}{m_a}\right)^{7/6}$$

(Athermal Production Mechanism)

Mass and Couplings

Generically: $m_a \sim g_{aii} \sim \frac{1}{f_a}$

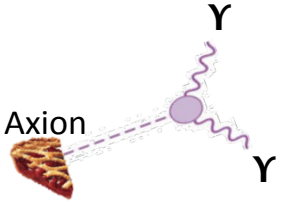
Preferred Mass Range

10^{-6} eV < m_a < 10^{-2} eV

(potentially too much dark matter) (too coupled)

Coupling to Photons

Photon coupling $g_{a\gamma\gamma} = \frac{\alpha g_\gamma}{\pi f_a}$



$$g_\gamma^2 = \begin{cases} 0.94 KSVZ \\ 0.13 DFSZ \end{cases}$$

Hunting Axions is like playing a game of Battleship

Experimental Perspective on DM Axions

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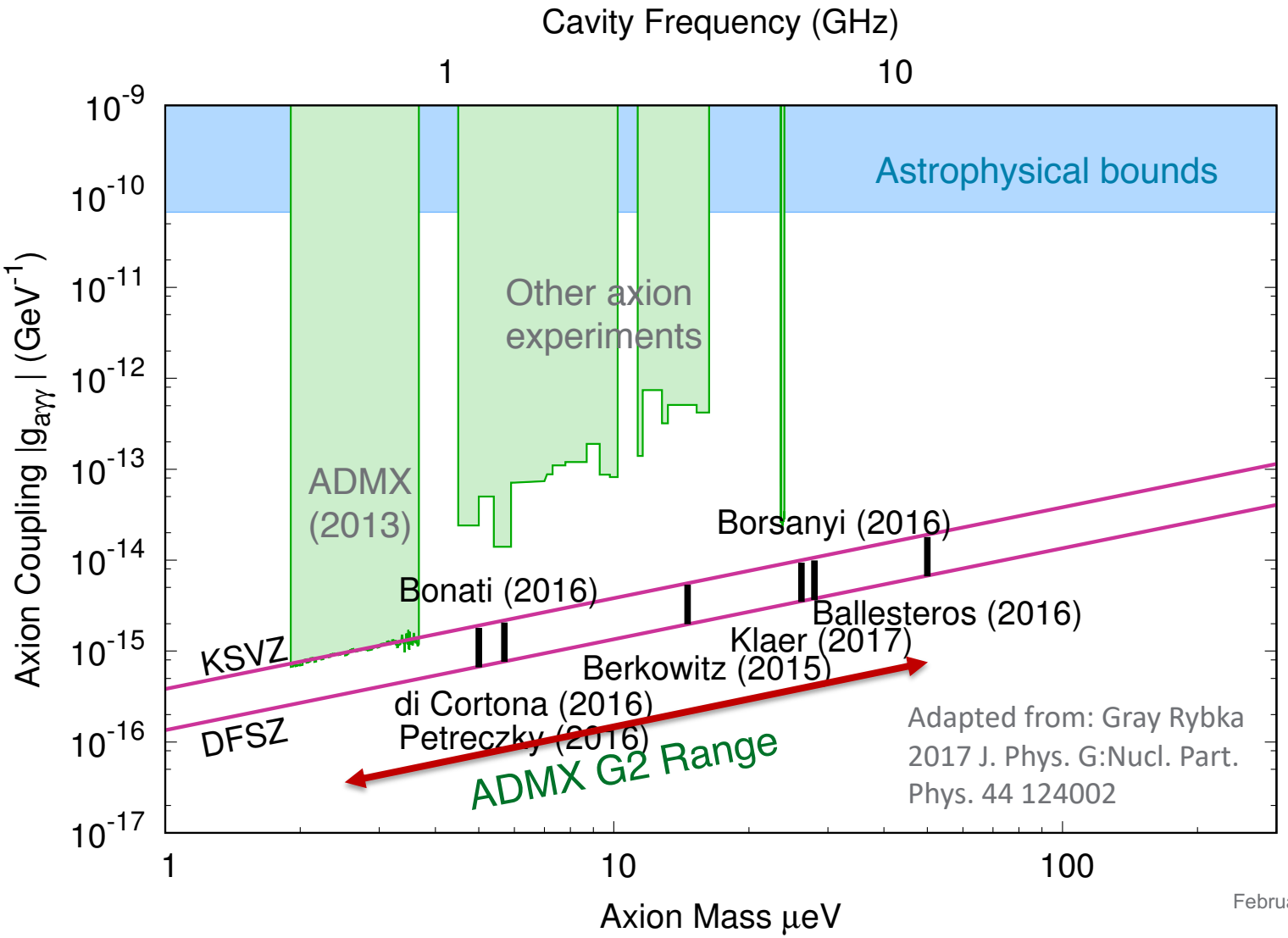
Analytic and Lattice predictions of the axion mass, given it makes 100% Dark matter



The ADMX Program

ADMX
AXION DARK MATTER EXPERIMENT

ADMX G2 at U. Washington
Scientific American, 2015

Goal: Find Dark Matter axions, or exclude them at high confidence

Collaborating Institutions:
UW, UFL, PNNL
FNAL, UCB, LLNL
LANL, NRAO, WU, Sheffield

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How to Search for Dark Matter Axions

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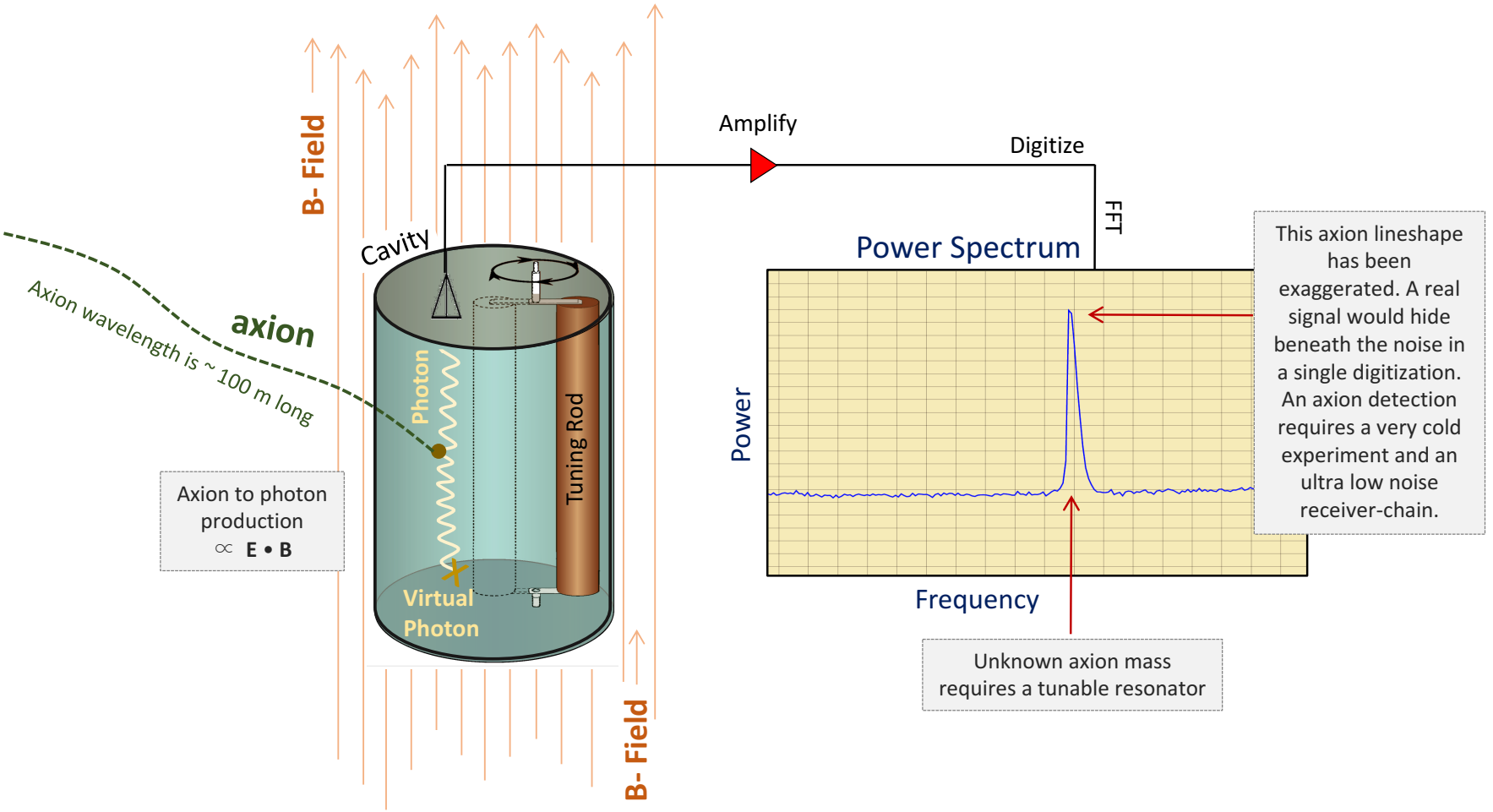
The Axion Haloscope



ADMX Design

Field Cancellation Coil

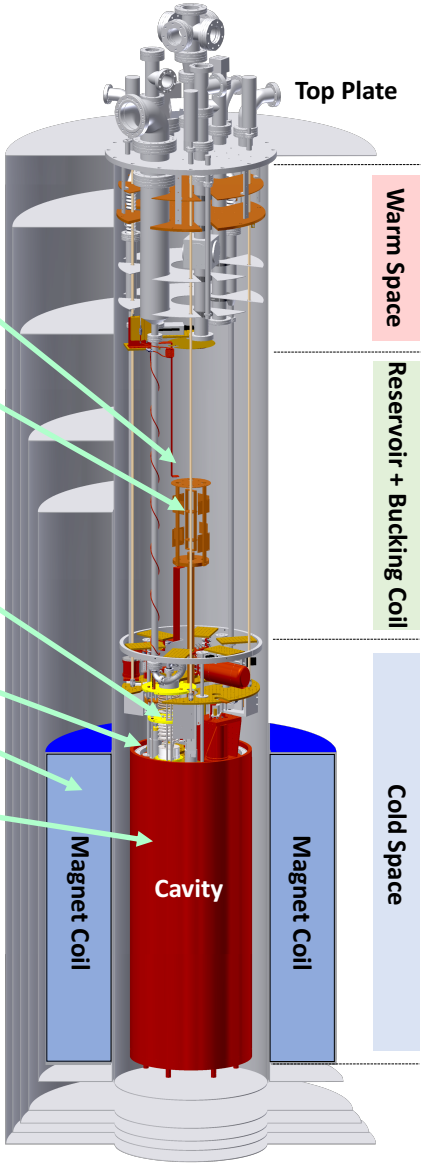
SQUID Amplifier Package

Dilution Refrigerator

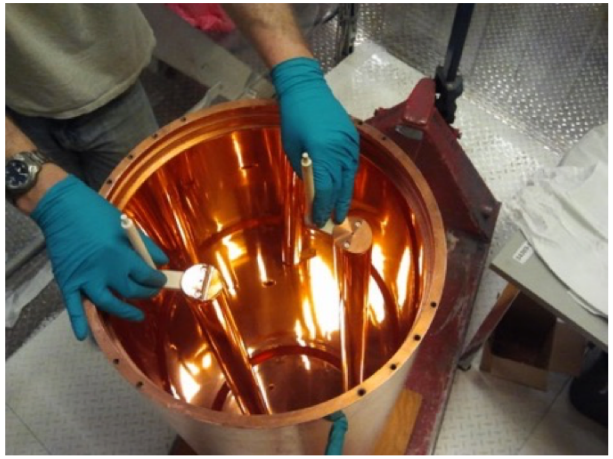
Antennas

8 Tesla Solenoid Magnet

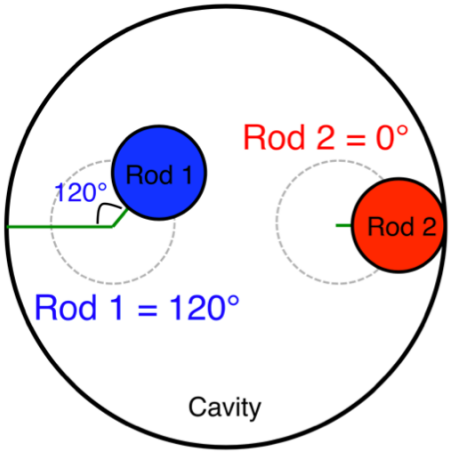
Microwave Cavity

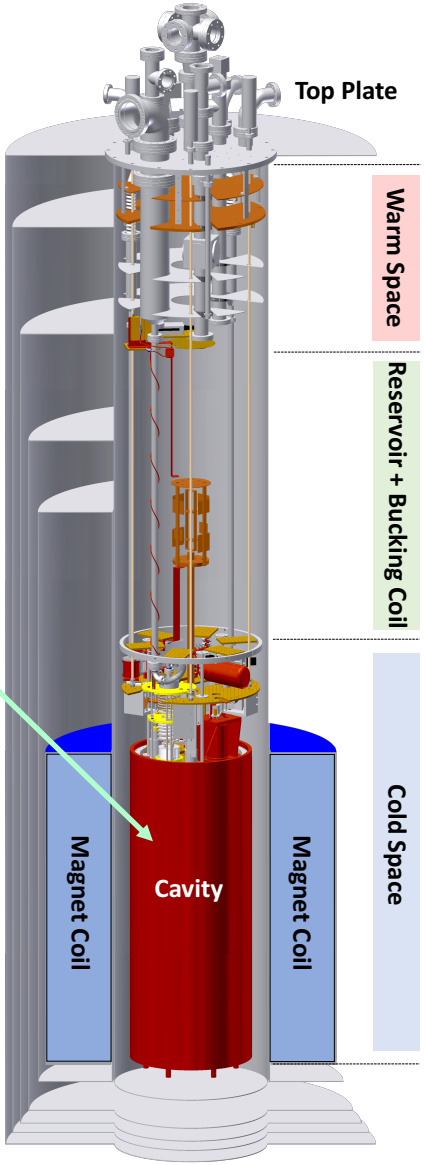


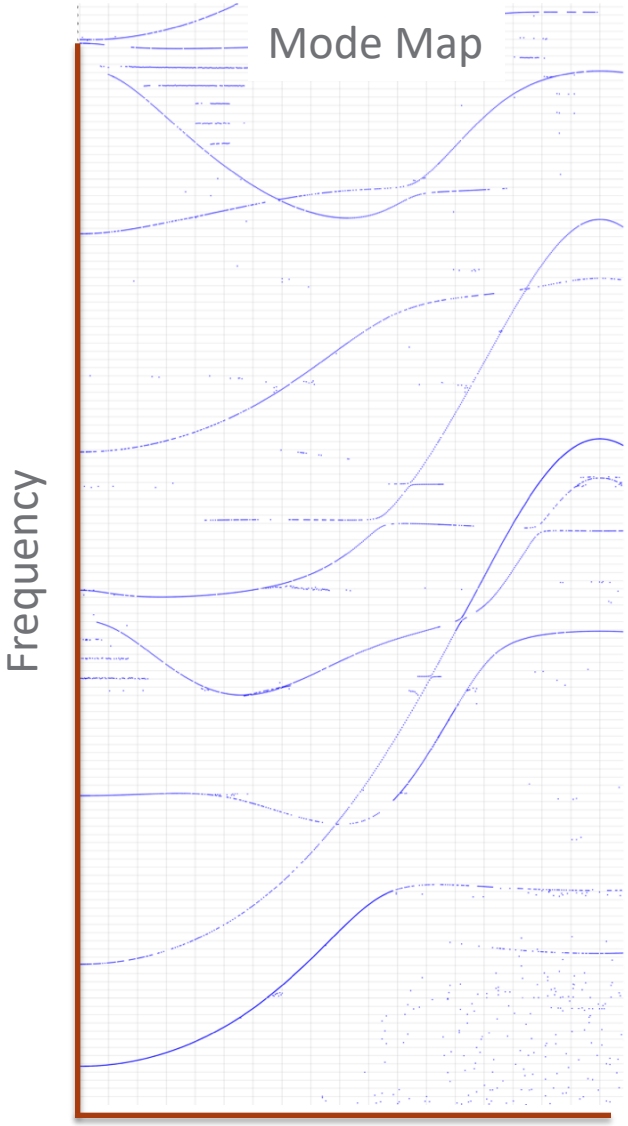
ADMX Design: Cavity



Microwave Cavity



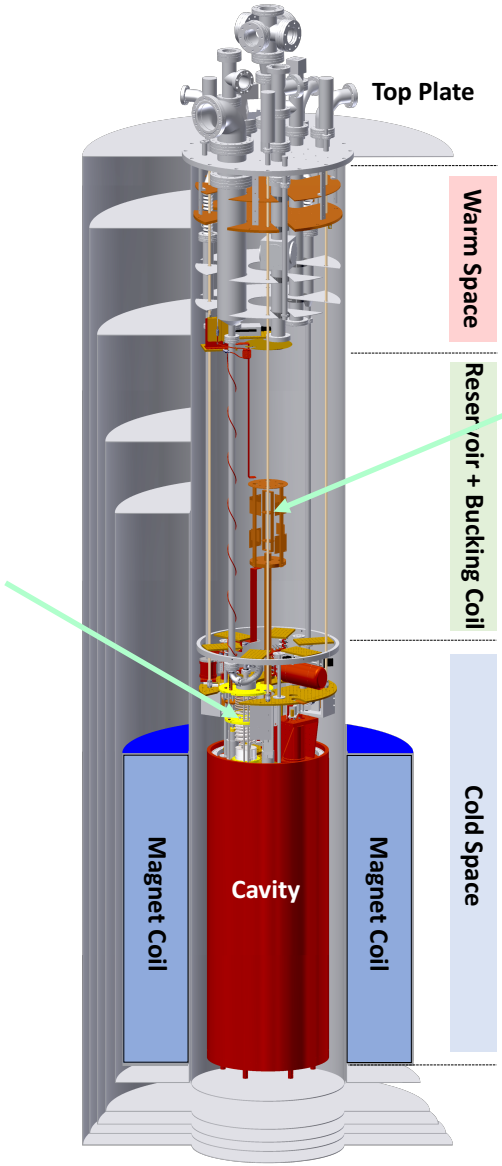




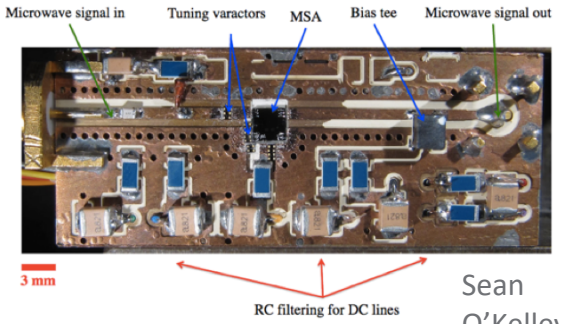
ADMX Design: Reducing Noise

Dilution Refrigerator

Dilution Refrigerator installed above ADMX Cavity



ADMX Tunable MSA



Sean O'Kelley, Clarke Group, UC Berkeley

ADMX JPA

Yanjie Qiu, Siddiqi Group, UC Berkeley

Figures from 2nd Workshop of Microwave Cavities and Detectors for Axion Research

ADMX Receiver

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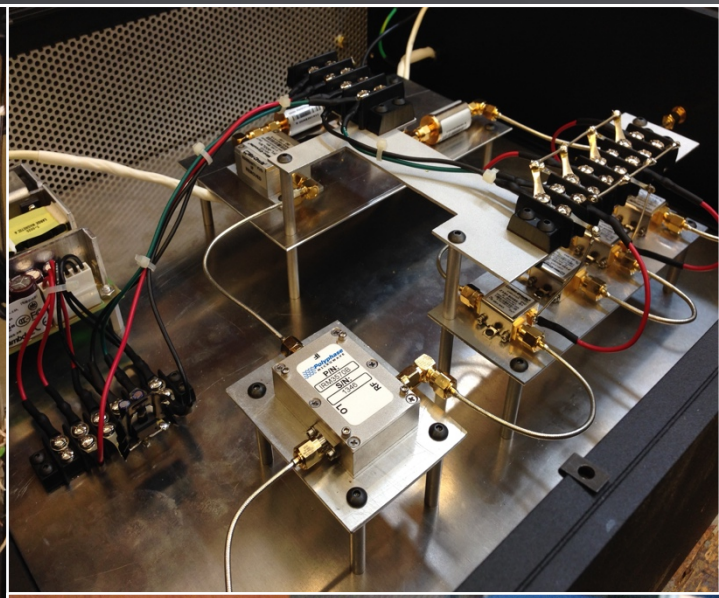

Synthetic Axion Generator

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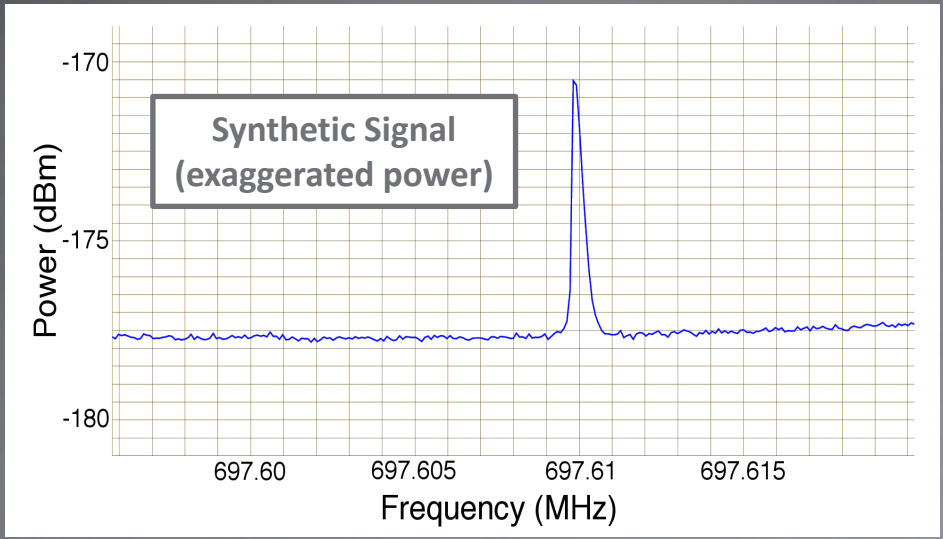
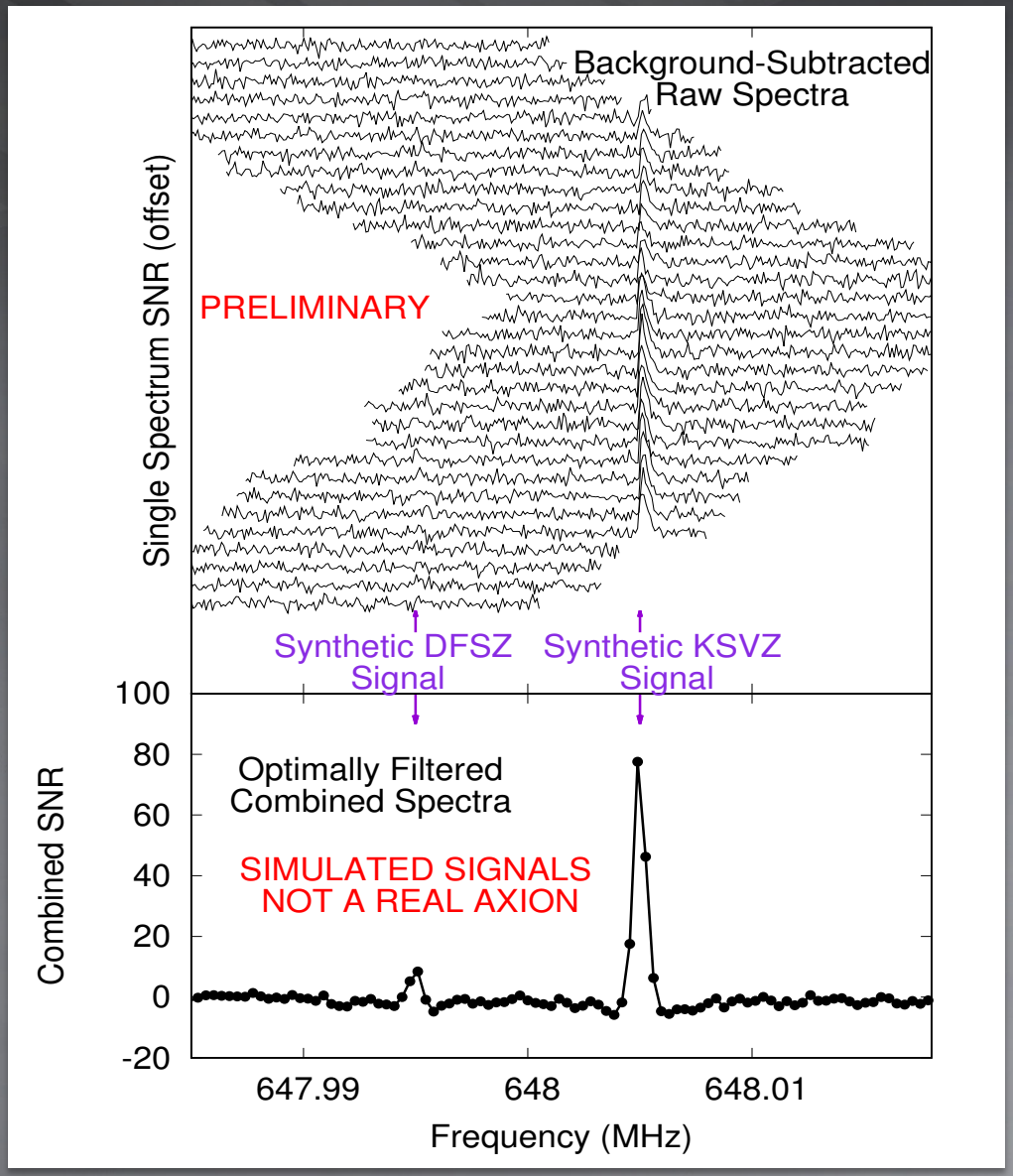
Synthetic RF signals are be generated externally to verify sensitivity and test the detection process

Synthetic Axion through the cavity and receiver-chain



Synthetic Axion Generator

Analysis of Software Injected Signals in Real Data



Synthetic signals are software-injected to evaluate analysis.

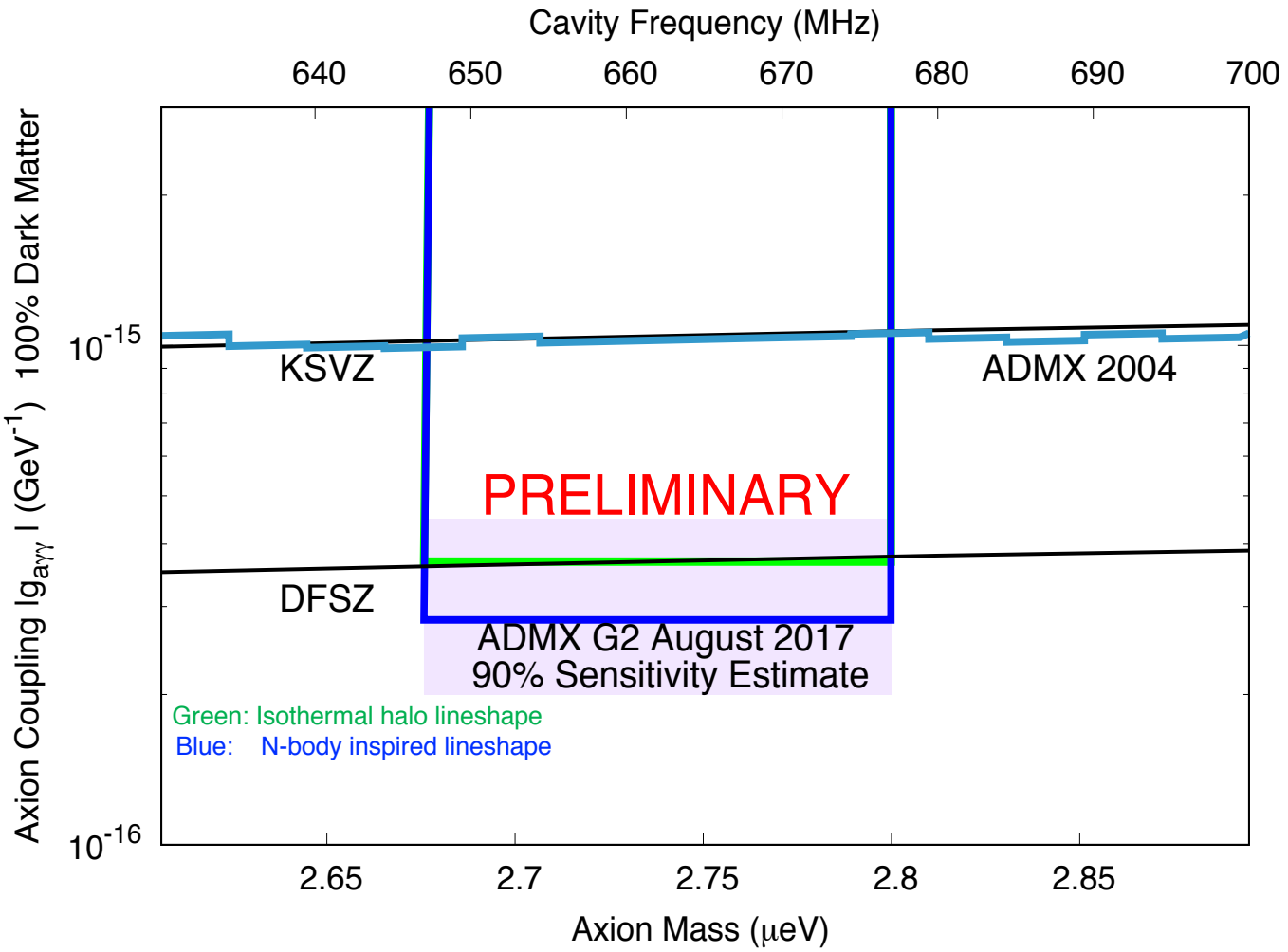
A KSVZ and DFSZ axion signal (N-body lineshape) are shown here.

Conclusion:
DFSZ axion signals should be very clear in analysis if present

ADMX G2 Operations

- The cavity frequency is scanned over a region until the desired SNR is achieved (645 - 675 MHz)
- We then examine the combined power spectrum for signs of excess
- Excess power regions can be statistical fluctuations, synthetically injected signals, RF interference, or axions
- Excess power regions are rescanned to see if they persist
- Persistent candidates are subjected to a variety of confirmation tests

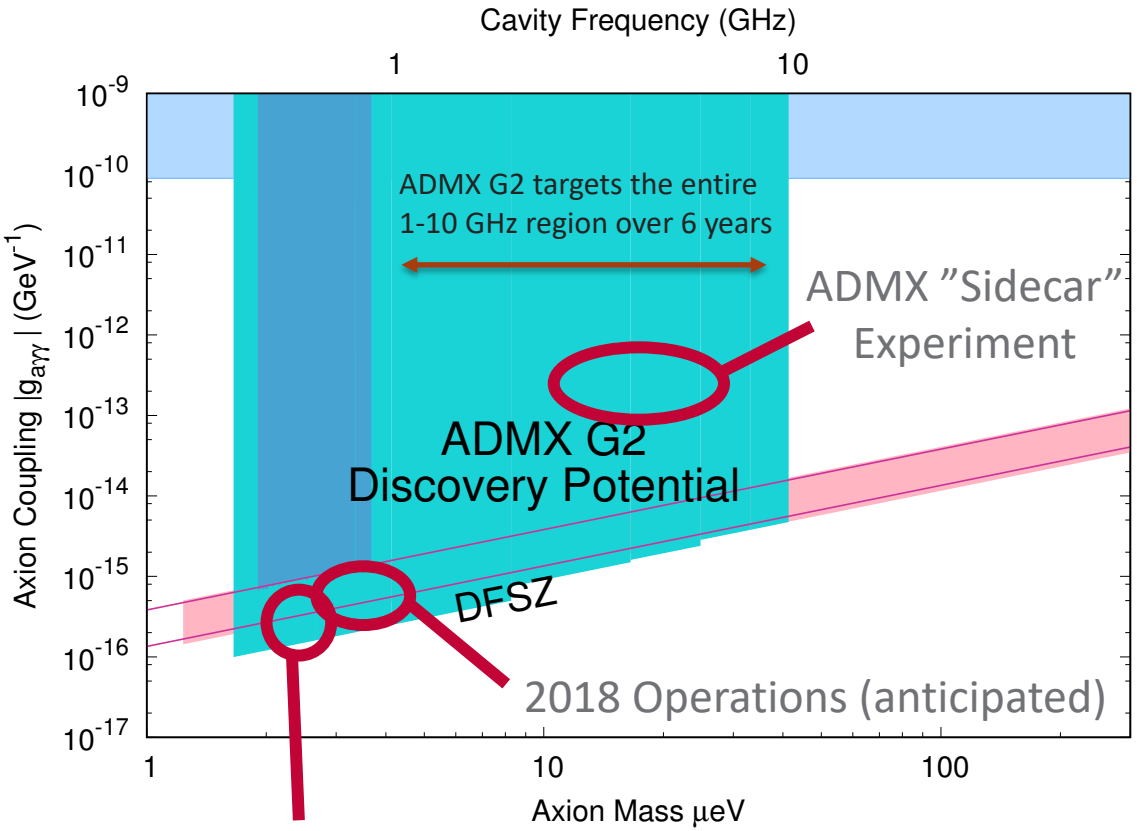
Preliminary Sensitivity Estimate



ADMX G2 – Current Status

We could find the axion at any time!

- Currently ADMX is scanning 700-890 MHz
- We anticipate faster frequency coverage in the future due to:
  - Higher magnetic field
  - Lower temperatures
  - Less time spent doing engineering studies



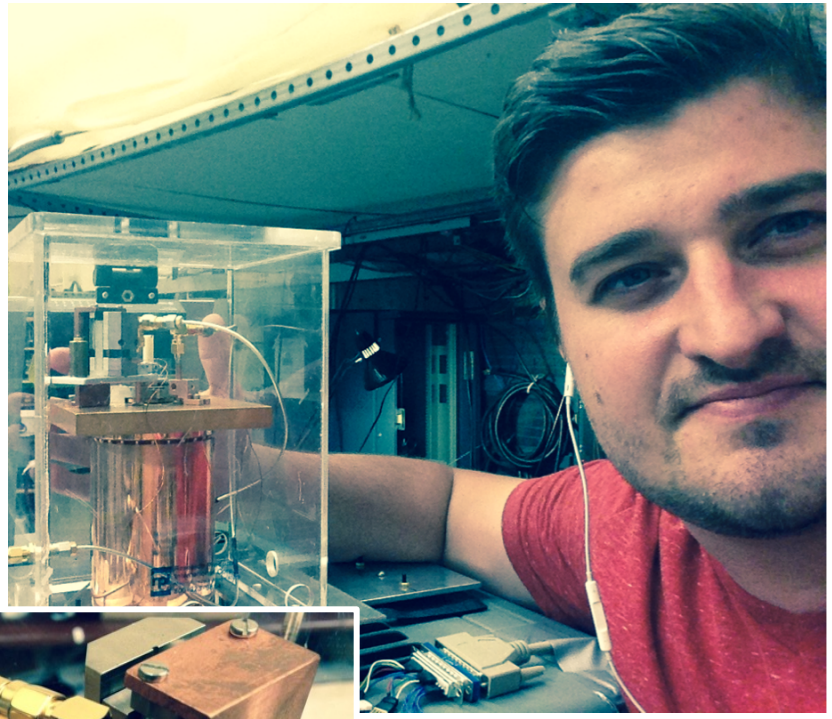
2017 Operations (Completed)

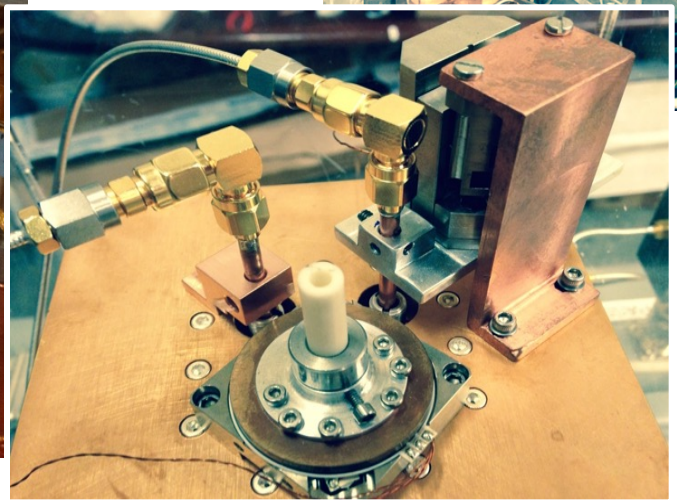
ADMX "Sidecar"

Smaller cavity =
higher-mass axion search

Characteristic Frequency:
TM010: 4-6 GHz
TM020: 7 GHz

Prototype: not yet sensitive to QCD axions





Preliminary ADMX Sidecar Sensitivity Estimate (data from 2016-2017)

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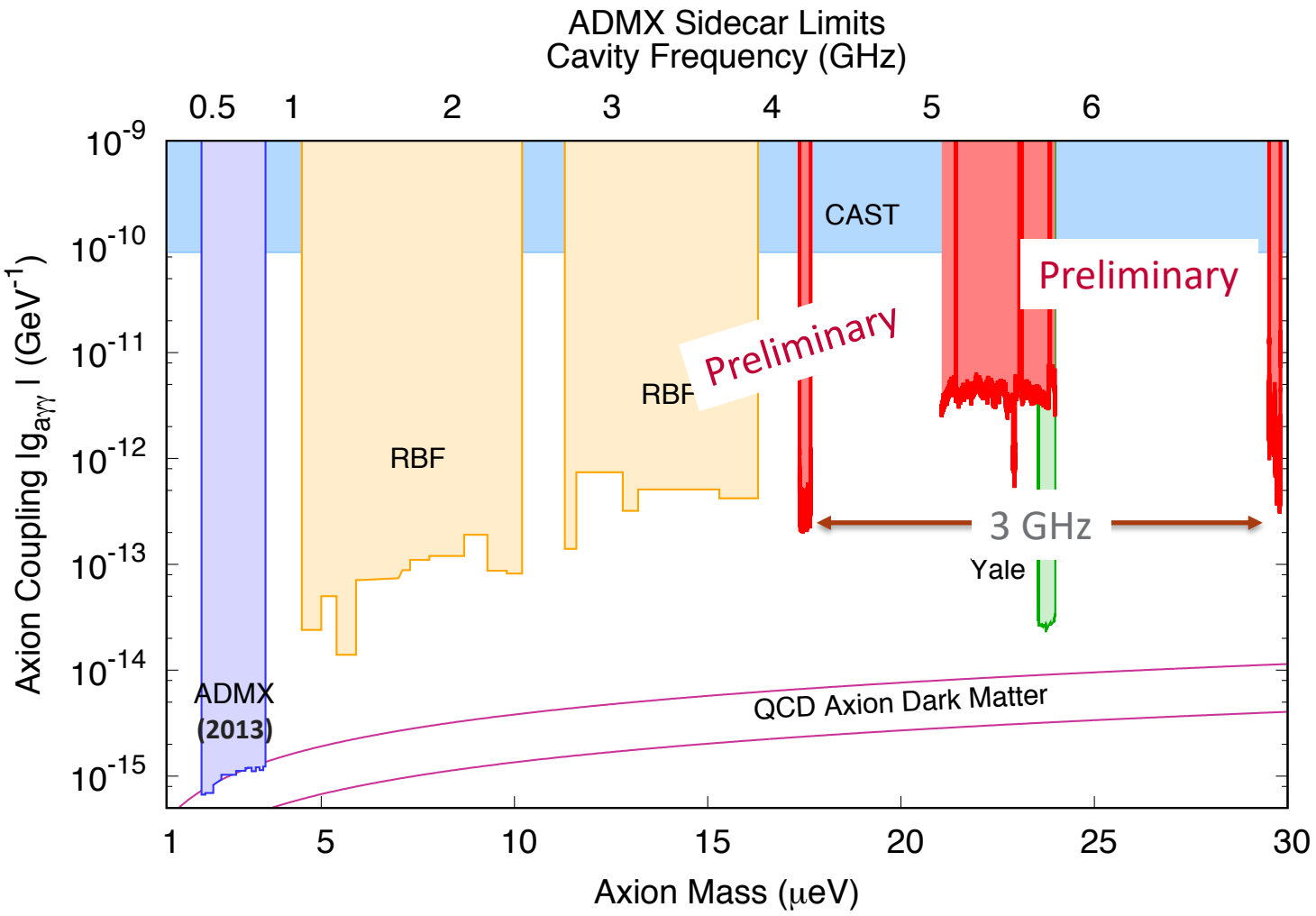
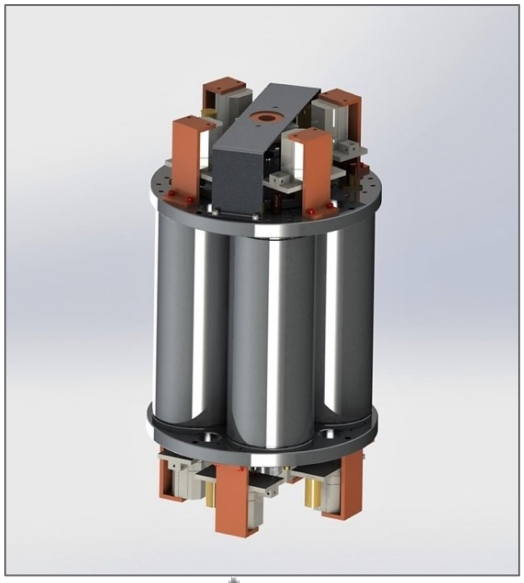
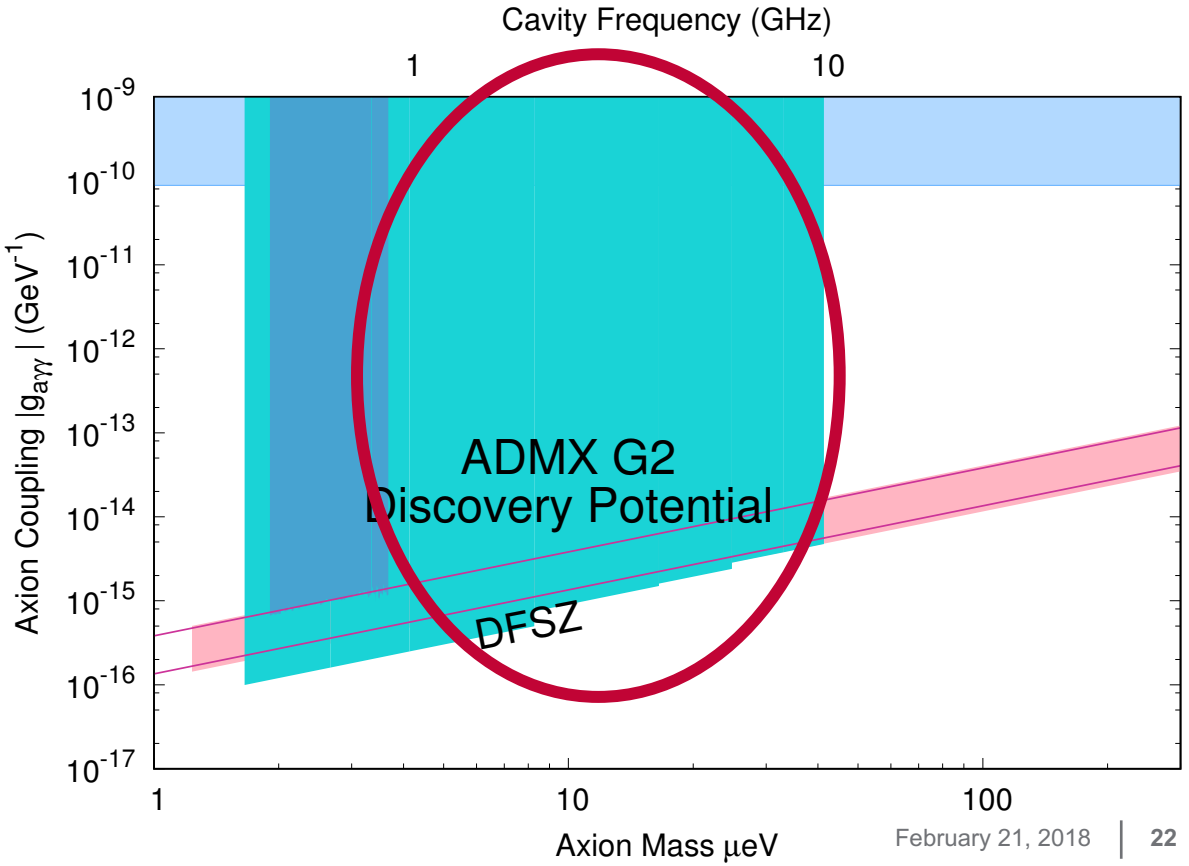


ADMX G2 Multi-Cavity Systems



Multi-cavity system designs being finalized.

New technical challenge: Tuning a bunch of cavities to the same frequency quickly.



Pacific Northwest National Laboratory (PNNL) Building ADMX Cavity Frequency Locking System

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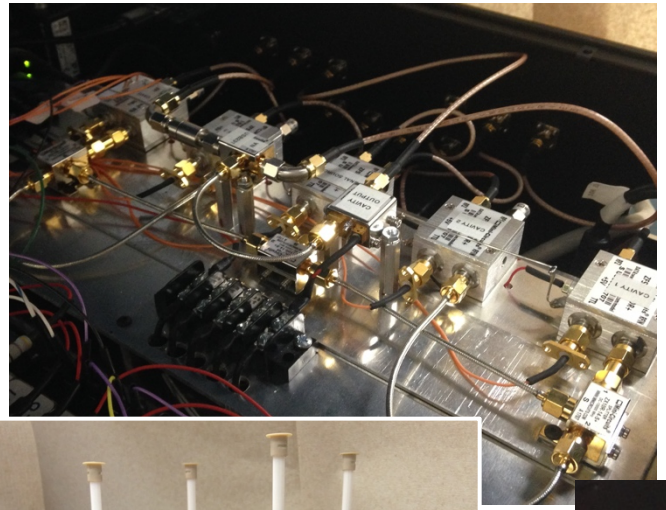

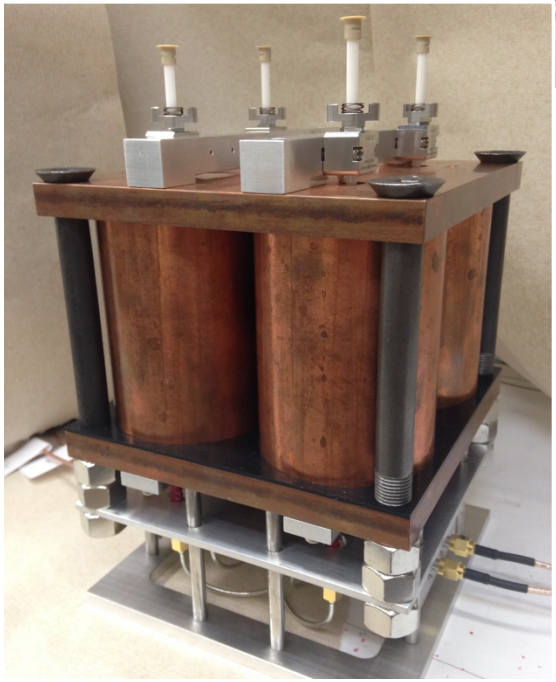

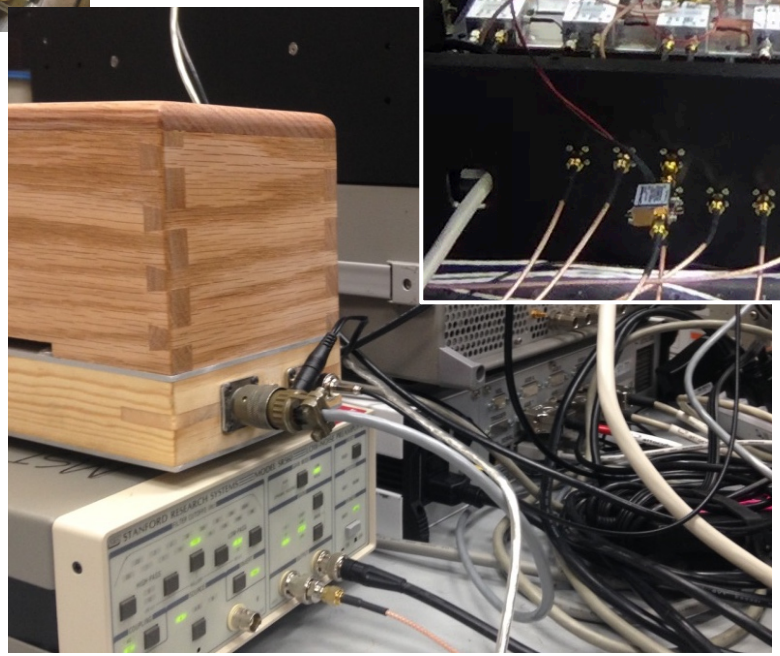

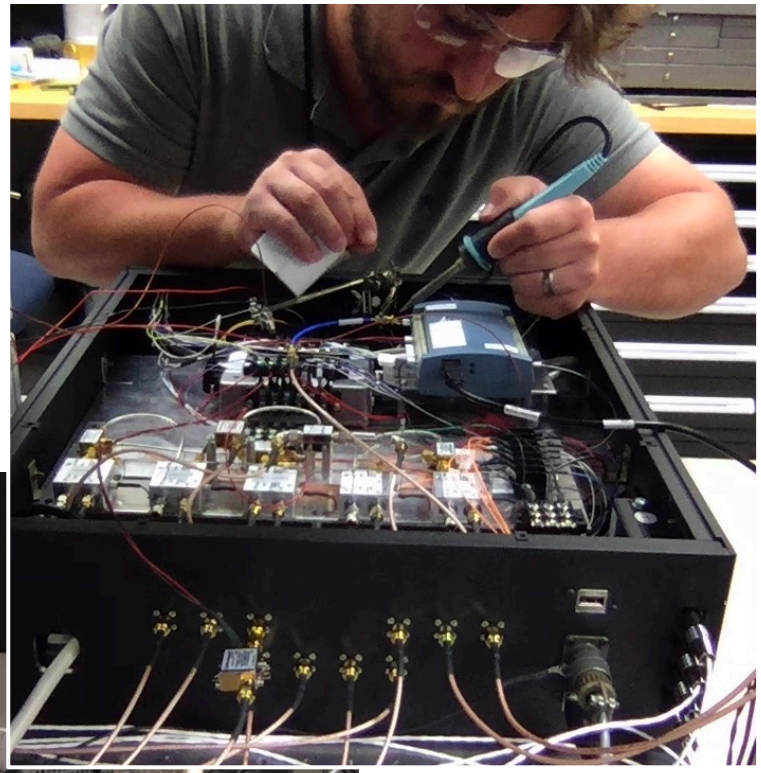

Conclusions

Axions are worth looking for

ADMX Gen 2 is the first and only experiment with DFSZ sensitivity in the ideal dark matter axion mass range

In two years, ADMX Gen 2 will be sensitive to dark matter axions up to 8.2 ueV

We will follow that with operations up to 40 ueV

Discovery could come at any time!