ADMX
AXION DARK MATTER EXPERIMENT

ADMX Current Results and Status

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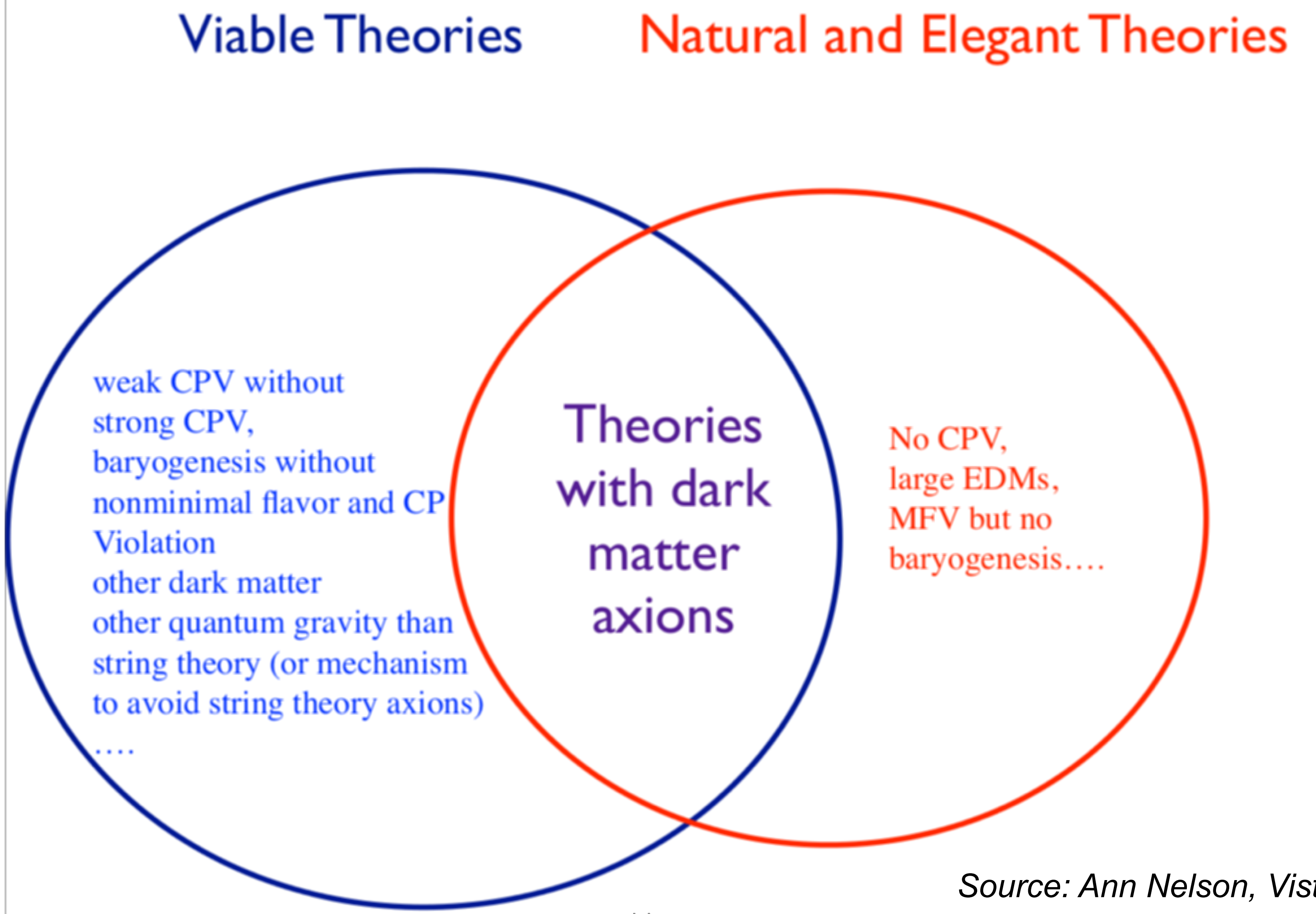
PATRAS 2019

Axions: The Natural, Elegant Solution



Source: Ann Nelson, Vistas in Axion Physics 2012

ADMX "G2" Dark Matter Search: Find Dark Matter Axions

ADMX collaboration meeting, UW, December 2018

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

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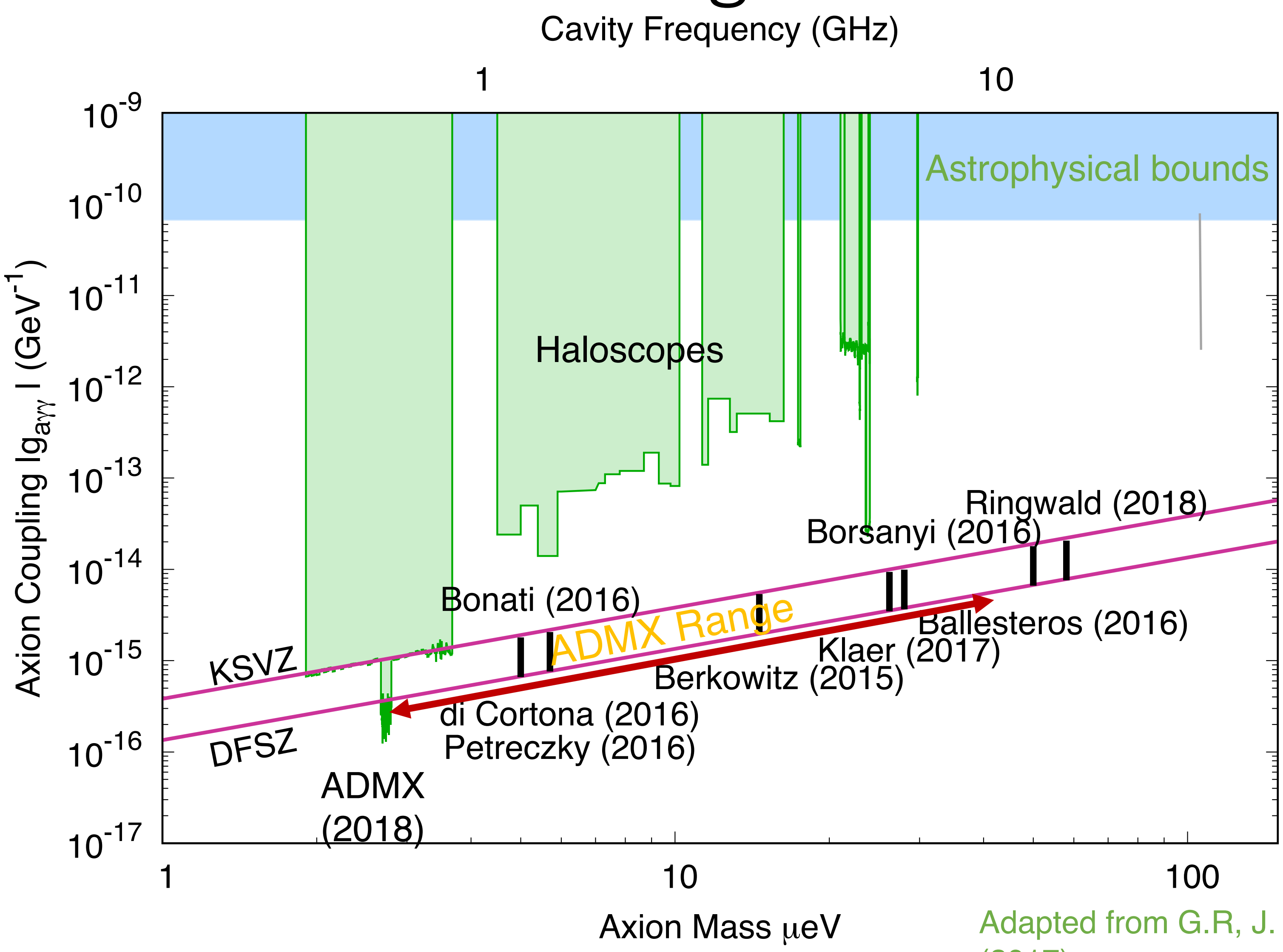
Also support from LLNL and PNNL LDRD programs
and R&D support the Heising-Simons institute

Where we're looking for Axion Dark Matter



Analytic and Lattice predictions for the "classical" QCD axion mass making 100% dark matter, created post-inflation, does not include string/domain wall contributions.

Adapted from G.R, J. Phys. G (2017)

There is strong motivation for dark matter to be made of axions in the 1-10 GHz range

ADMX G2 starting at 600 MHz and working its way upward searching for axion dark matter with sensitivity to both KSVZ and DFSZ coupling models

Status:

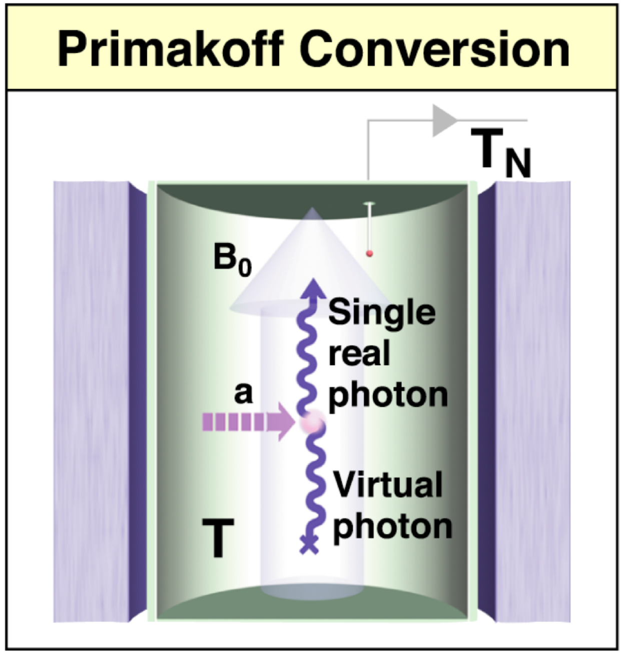
640-680 MHz – covered (10.1103/PhysRevLett.120.151301)

680-800 MHz – paper in preparation

800-1000 MHz - operations this year

1000 MHz + - future years

Axion Haloscope: How to search for Dark Matter Axions



Dark Matter Axions will convert to photons in a magnetic field.

The conversion rate is enhanced if the photon’s frequency corresponds to a cavity’s resonant frequency.

Sikivie PRL 51:1415 (1983)

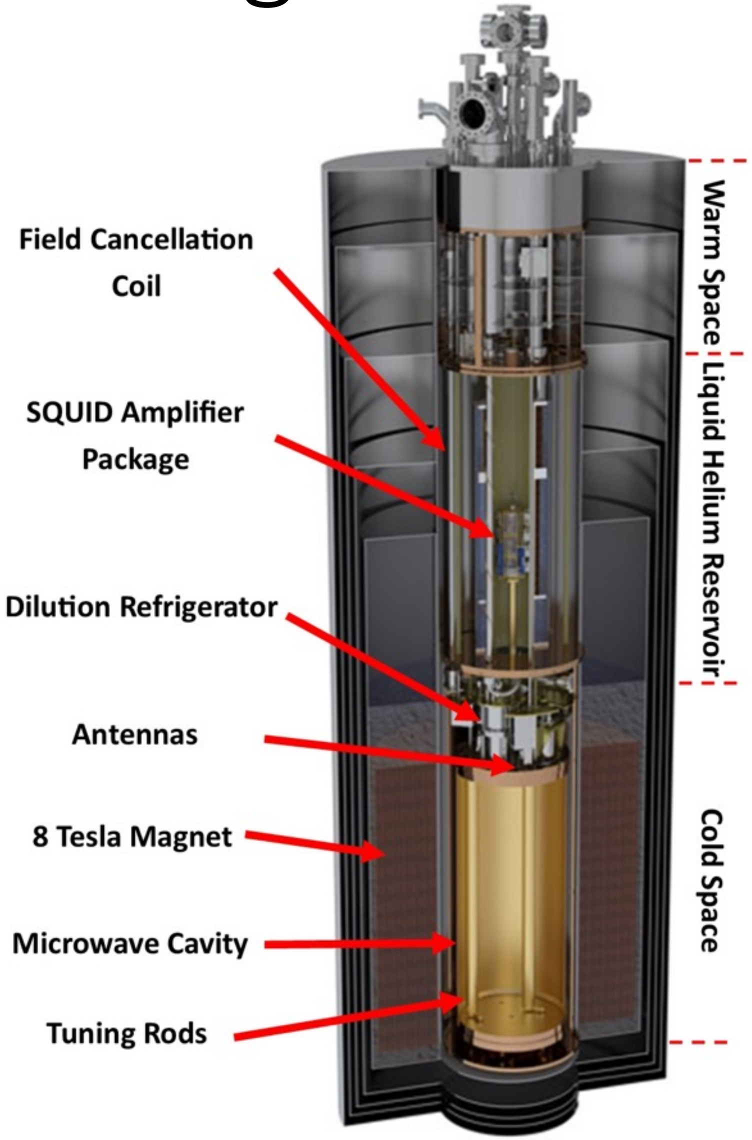
Signal Proportional to

Cavity Volume
Magnetic Field
Cavity Q

Noise Proportional to

Cavity Blackbody Radiation
Amplifier Noise

ADMX Design



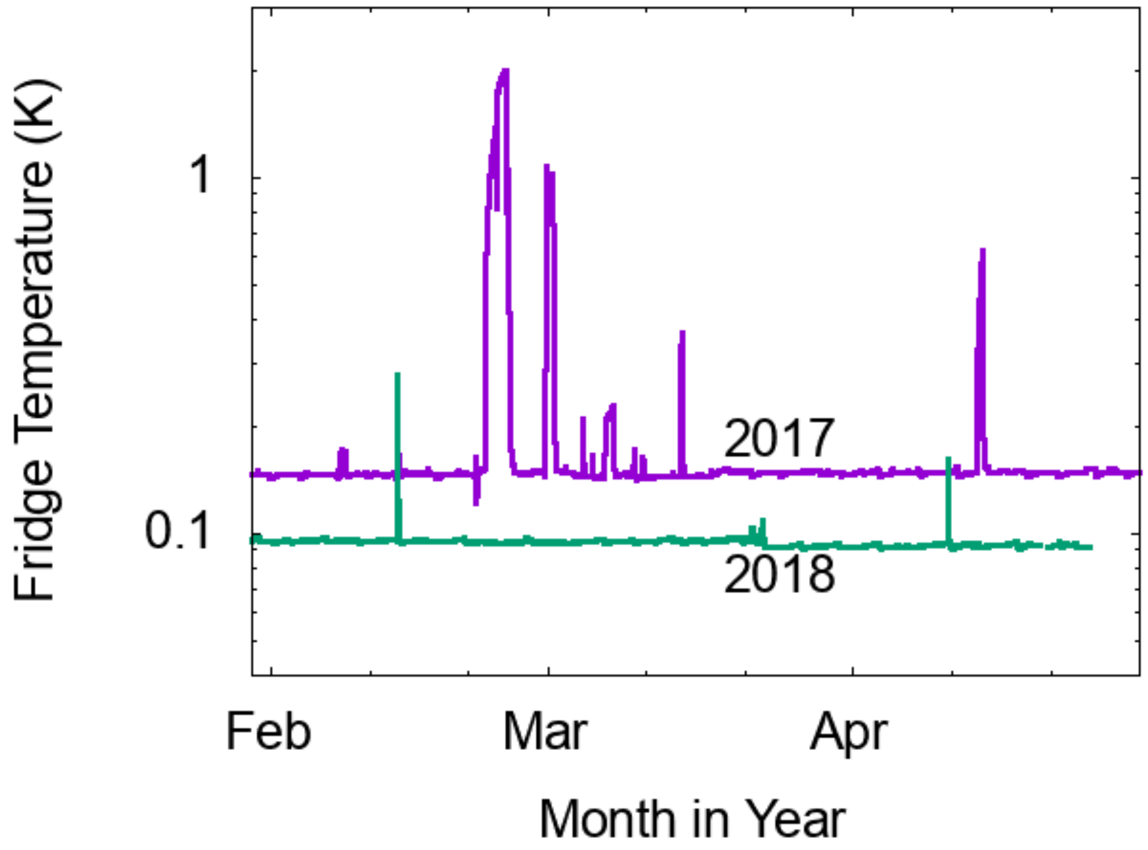
Key technologies:

-millikelvin cryogenics

-ultralow noise quantum amplifiers

2018 Operations: Cryogenics

Temperature for example weeks, 2017 vs 2018



We had a significantly lower temperature, and better noise in 2018

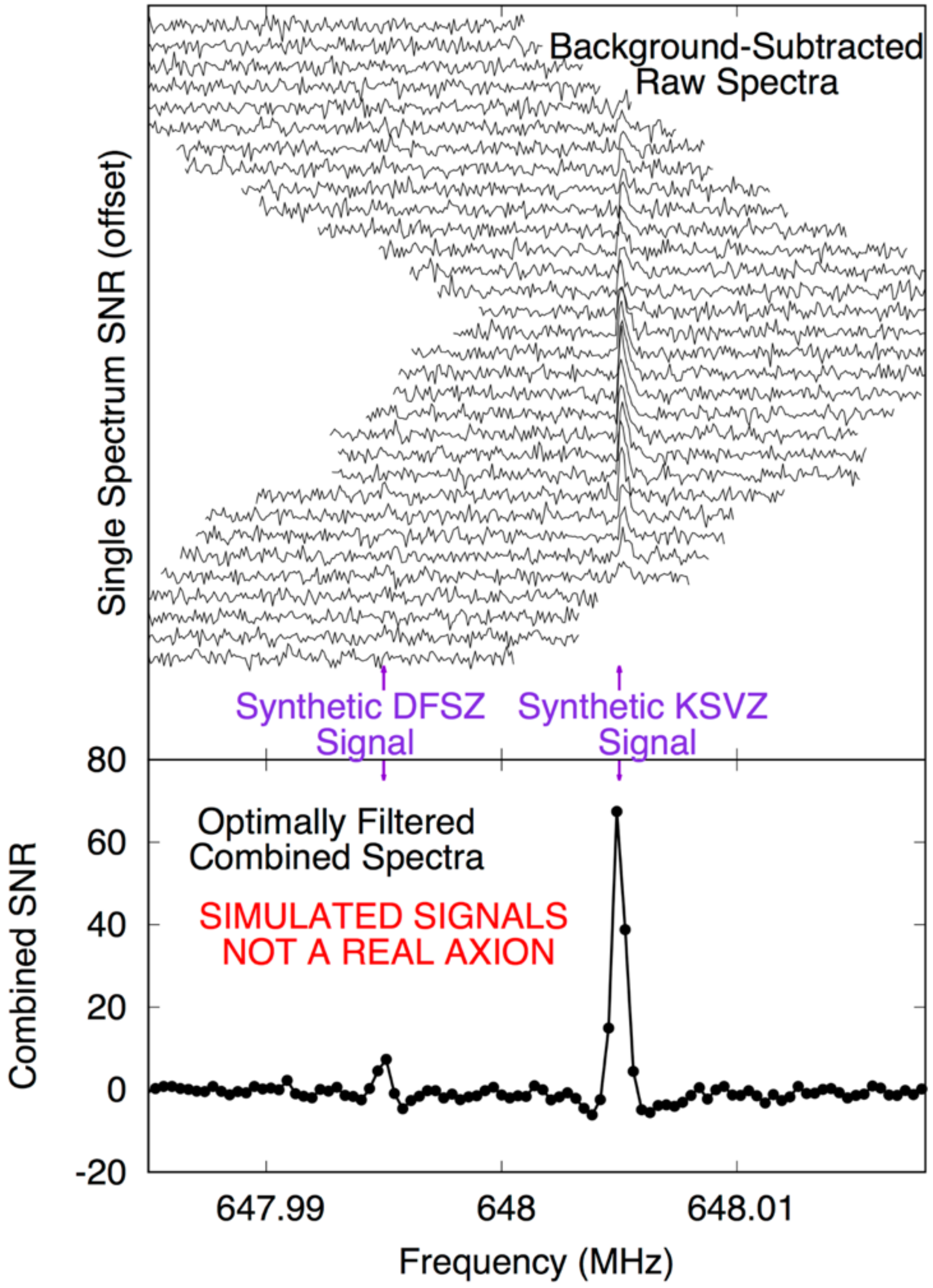
Scanning Technique

The cavity is scanned in few kHz steps with 100 seconds integration ime over the frequency range.

The power spectra are filtered for expected axion lineshapes

Multiple spectra are combined to reach our sensitivity. Candidate excesses are rescanned.

Transient candidates or candidates that do not follow cavity lineshape (RFI) can be vetoed.



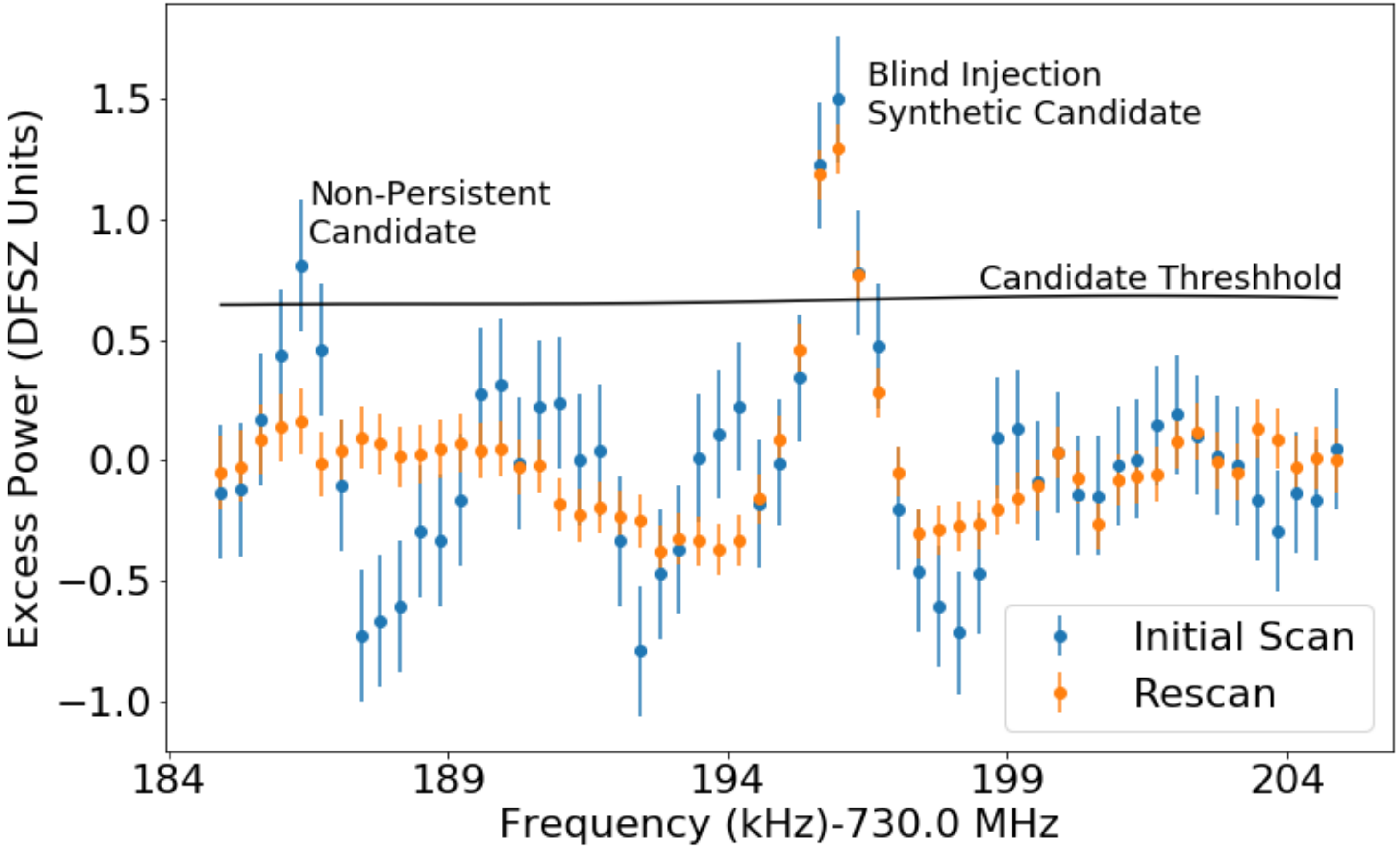
Synthetic Axion Signal Injection

Axion-shaped RF signal are periodically injected into the cavity, blind to the analysis.

Most signals are unblinded at the time of rescan to verify our detection efficiency.

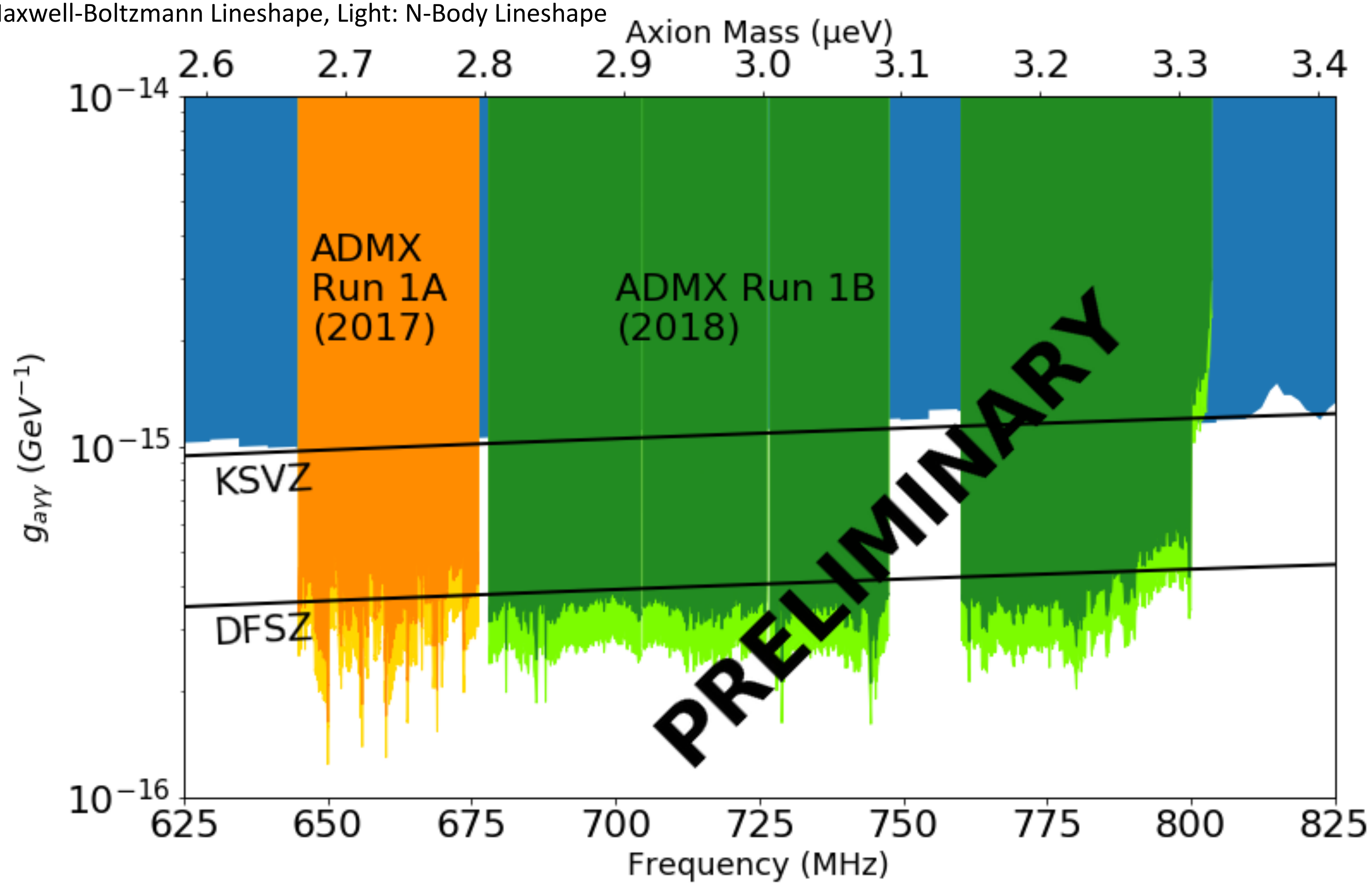
Some (like this one) are not unblinded until the decision to ramp the magnet down.

Note much more data is required in a rescan than during the initial scan.



Preliminary Sensitivity from 2018 Run

Dark: Maxwell-Boltzmann Lineshape, Light: N-Body Lineshape



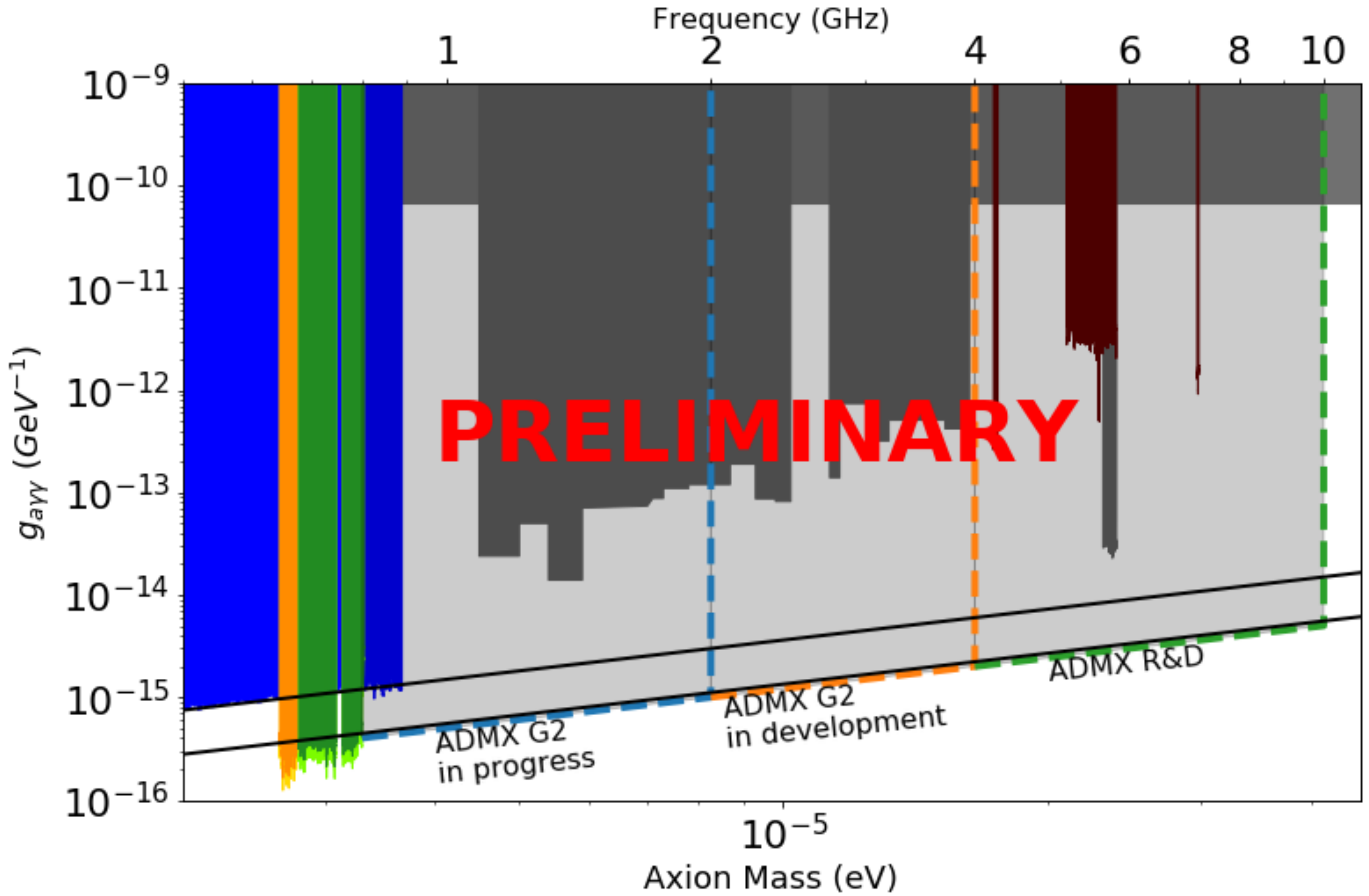
We estimate sensitivity to DFSZ dark matter axions between 2.8 and 3.3 ueV

This is four times as much mass range with much more even DFSZ coverage.

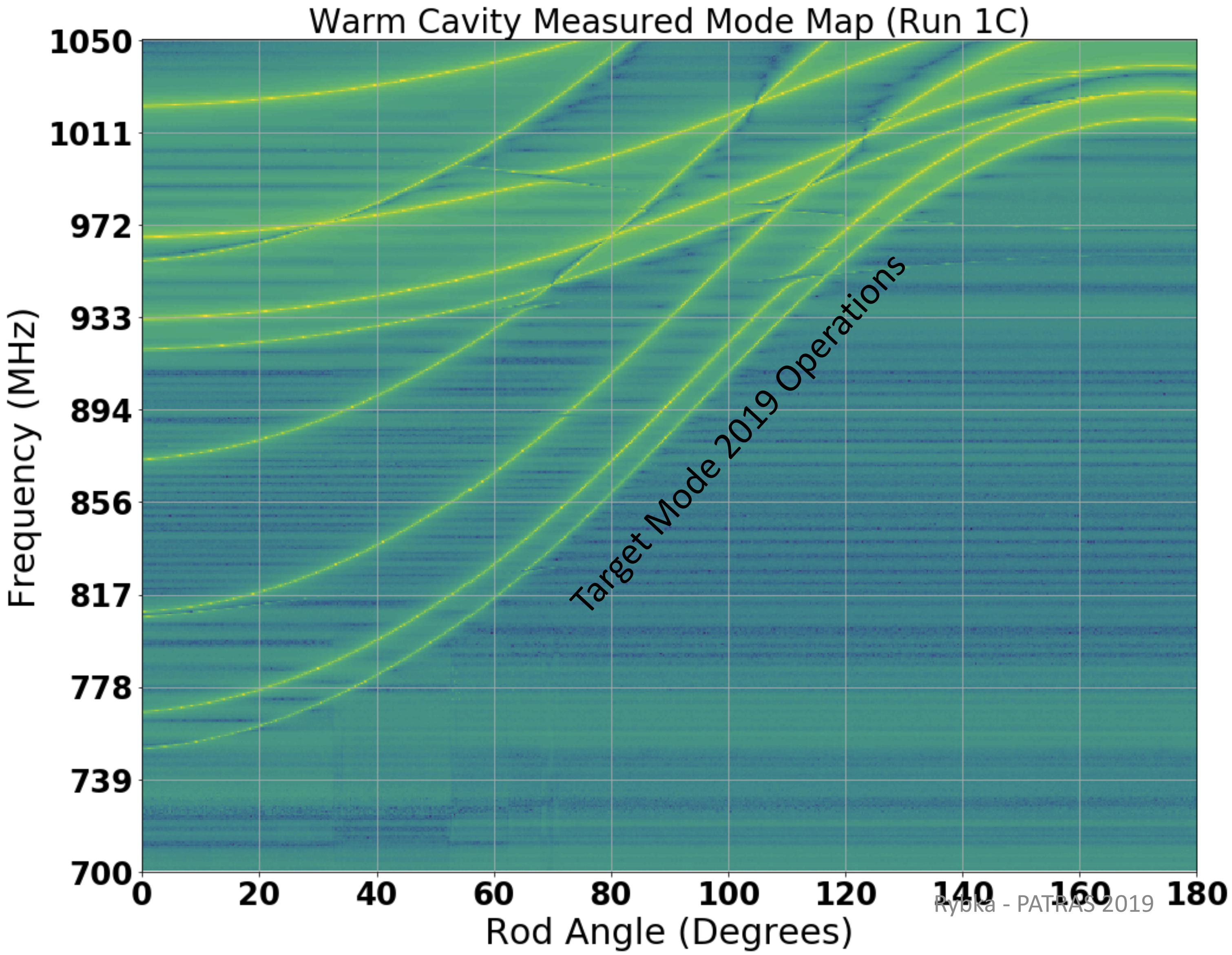
3 Gaps from mode crossings in cavity.

Paper in preparation!

Moving to Higher Frequencies



2019 Target



Expected Improvements for 2019

-smaller mode crossings

-better cryogenics and noise temperature

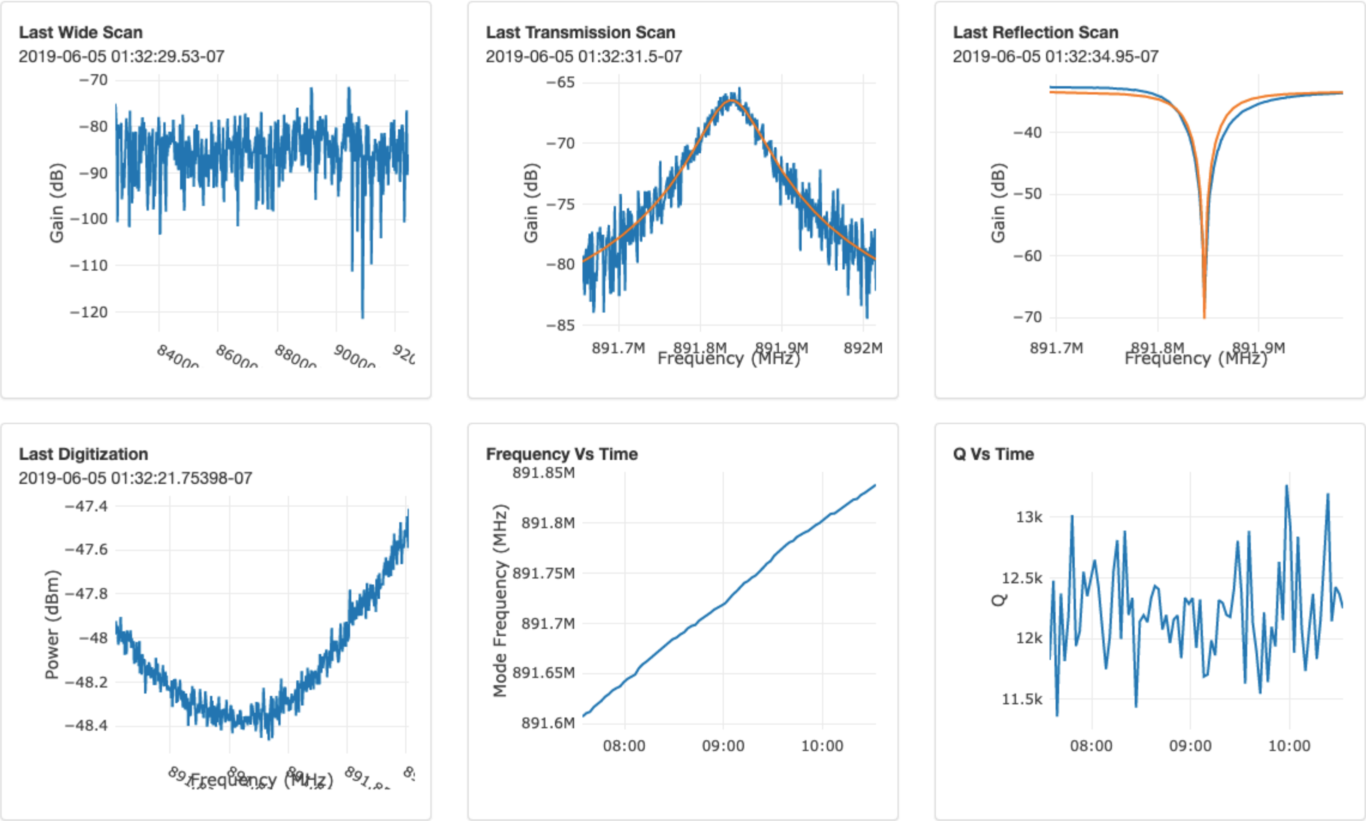
-lower dead time

-more efficient operation

-wider tuning range

= Better chance of finding the axion

2019 ADMX Status



Warm commissioning underway

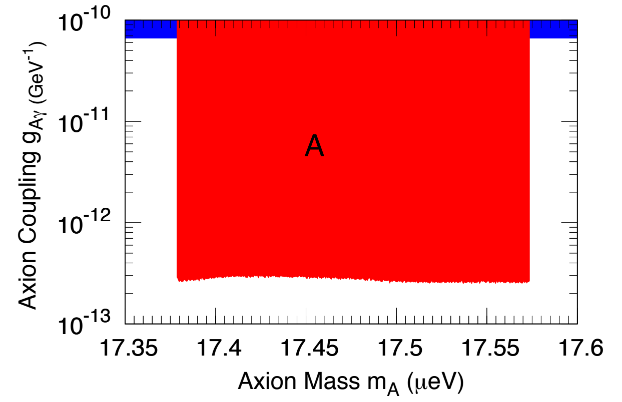
Scheduled for cooldown today!

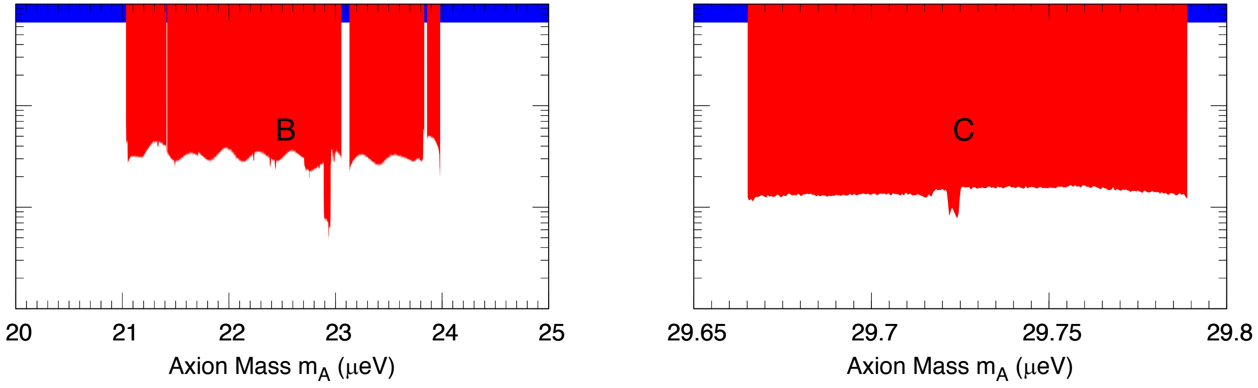
Moving to even higher frequencies

- ADMX will access higher frequencies by incorporating proven technologies:
  - Pizeoelectric Tuning
  - Multicavity systems
  - Wideband quantum amplifiers
- While also exploring more groundbreaking ideas
  - Squeezed states
  - Microwave photon counting

Higher Frequency Proof-of-Principles

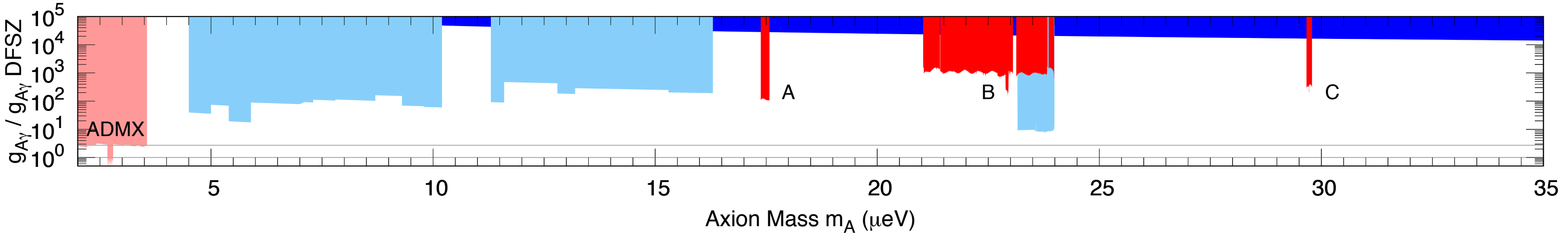
2017 Operations
- -Small-volume 'sidecar' demonstrator
- -Demonstration of higher-frequency technology
  - -Piezoelectric Tuning
  - -Higher-order modes
- -Traditional Quantum Amplifiers
- -New ALP Exclusion Limits at 17, 22, and 30 ueV
- -Boutan et al. **Phys. Rev. Lett. 121, 261302**





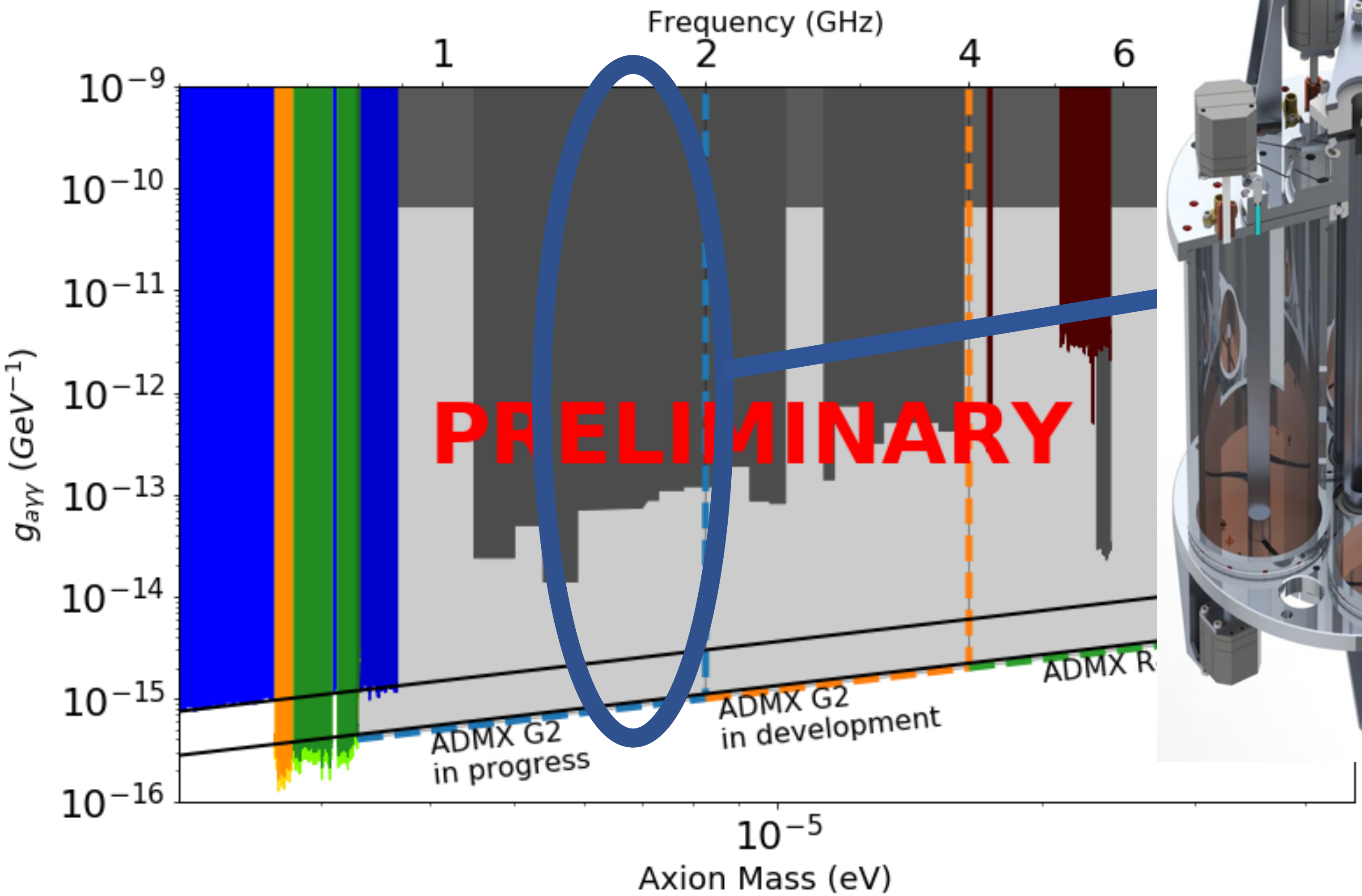
2018 Determinations
- Found that the 2017 piezo design worked better

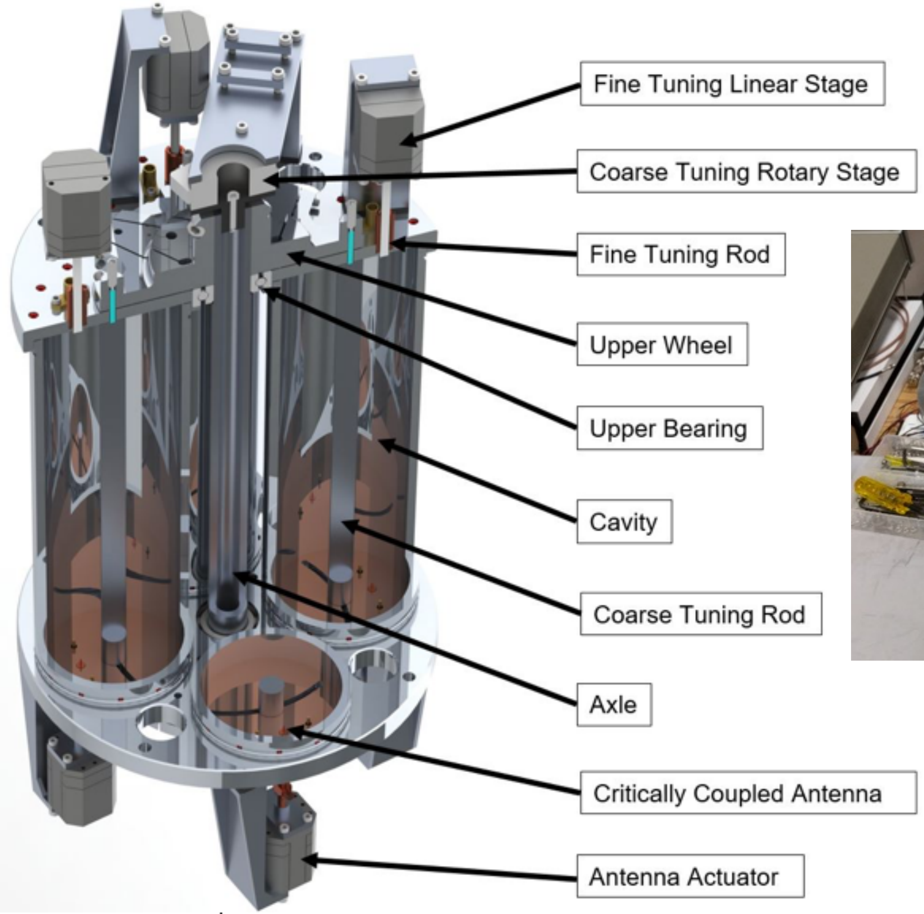
2019 Explorations
- Wideband Quantum Amplifiers
- Feedback systems
- Sensitivity to new frequency ranges

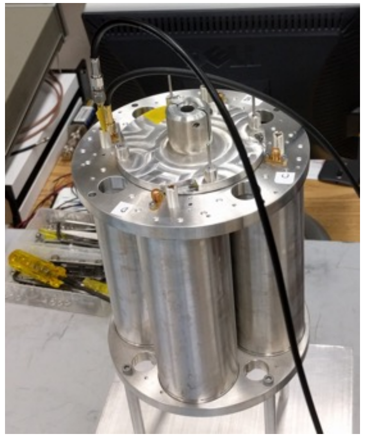


ADMX G2 – Multicavity Systems

Maintain detection volume at higher frequencies







Multicavity system 1-2 GHz
Prototype fabricated, tested

These people are great to work with!

Collaboration Opportunities!

- Reaching higher axion masses will take more people, more money, more work!
- The ADMX collaboration welcomes potential collaborators.
- There is especially room for more graduate students interested in analysis! We have far more data than we have students.

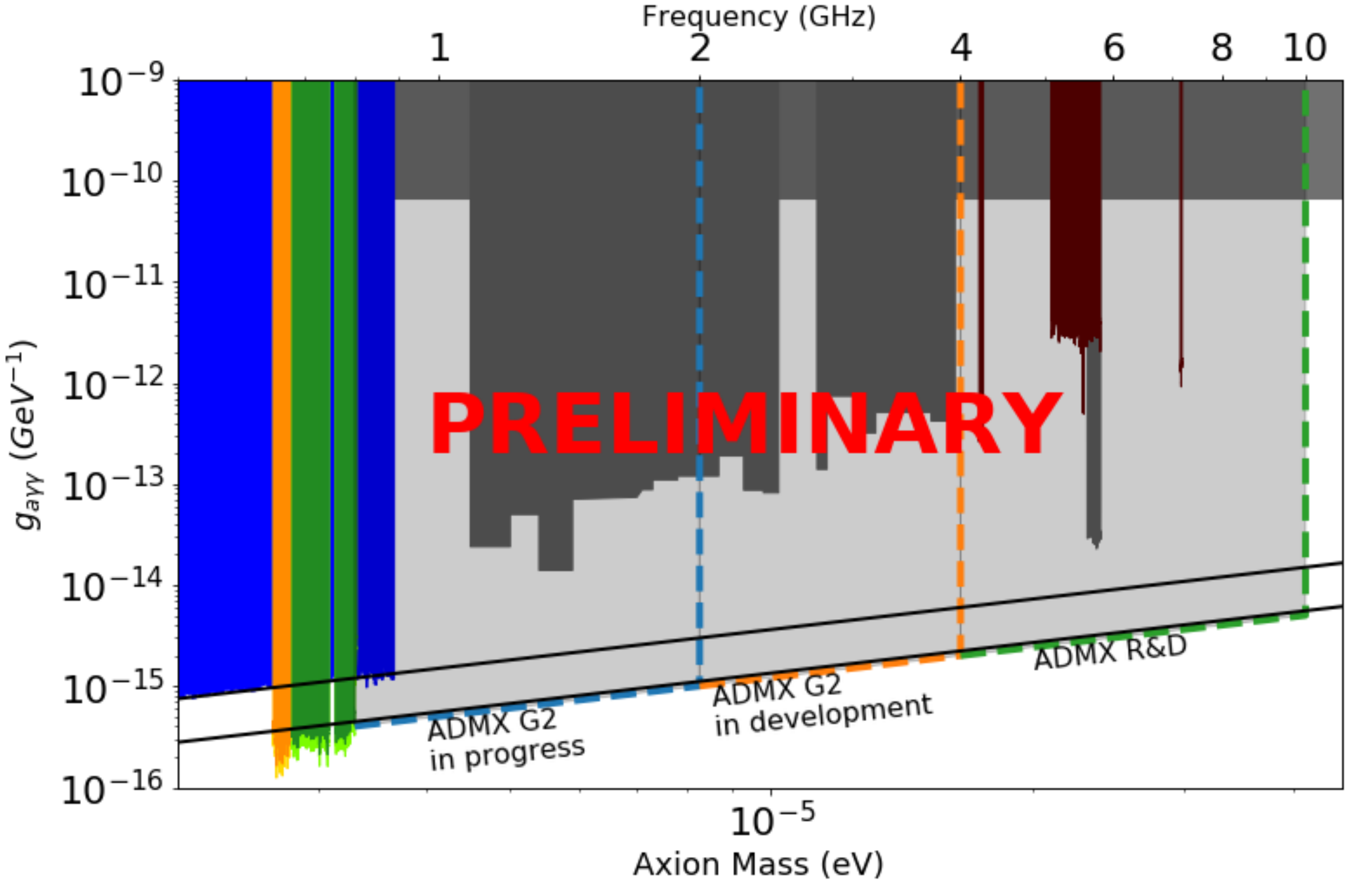
ADMX Conclusions

ADMX Gen 2 has operated with sensitivity to the DFSZ axions in the 2.7 ueV to 3.3 ueV

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

We are scanning up in mass, more quickly each year.

Discovery could come at any time!



Noise Calibration Backup Slide

Noise is calibrated from temperature sensors

Power vs Temperature fit yields system noise with JPA off

Power Increase / Gain Increase (SNRI) yields system noise with JPA on