An overview of Axion Dark Matter eXperiment:

current status and future plans

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On the behalf of ADMX Collaboration

QCD Axion as dark matter

- Solution of the strong CP problem
- Cosmological production as cold dark matter: pre (wide mass range) or post ($1\ \mu\mathrm{eV} \sim 1\ \mathrm{meV}$)-inflation misalignment
- Wave-like: mass $\ll$ 10 eV with occupancy number

$$N \approx \frac{\rho_{\mathrm{DM}}}{m} \lambda_{\mathrm{dB}}^3 \gg 1$$

De Broglie wavelength $$\lambda_{\mathrm{dB}} \approx \frac{2\pi}{mv}$$

WIMP dark matter (m ~ 100 GeV)	λ_{dB} ~ 10^{-13} m
Axion dark matter (m ~ 10^{-6} eV)	λ_{dB} ~ 100 m

ADMX Collaboration

Fermilab
THE UNIVERSITY OF WESTERN AUSTRALIA
Pacific Northwest NATIONAL LABORATORY
Lawrence Livermore National Laboratory
UF UNIVERSITY of FLORIDA
HEISING - SIMONS FOUNDATION
The University Of Sheffield.
Los Alamos NATIONAL LABORATORY
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
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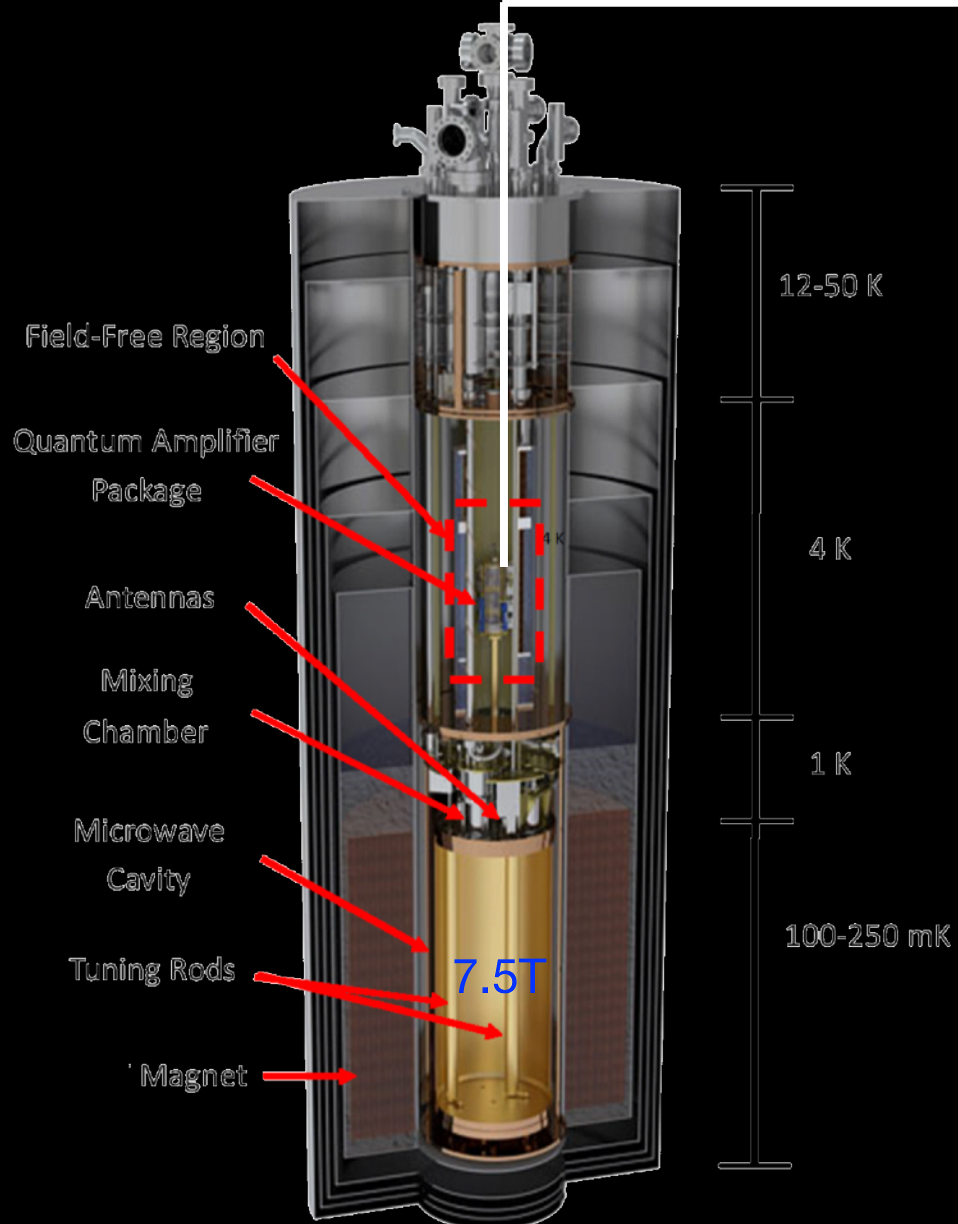
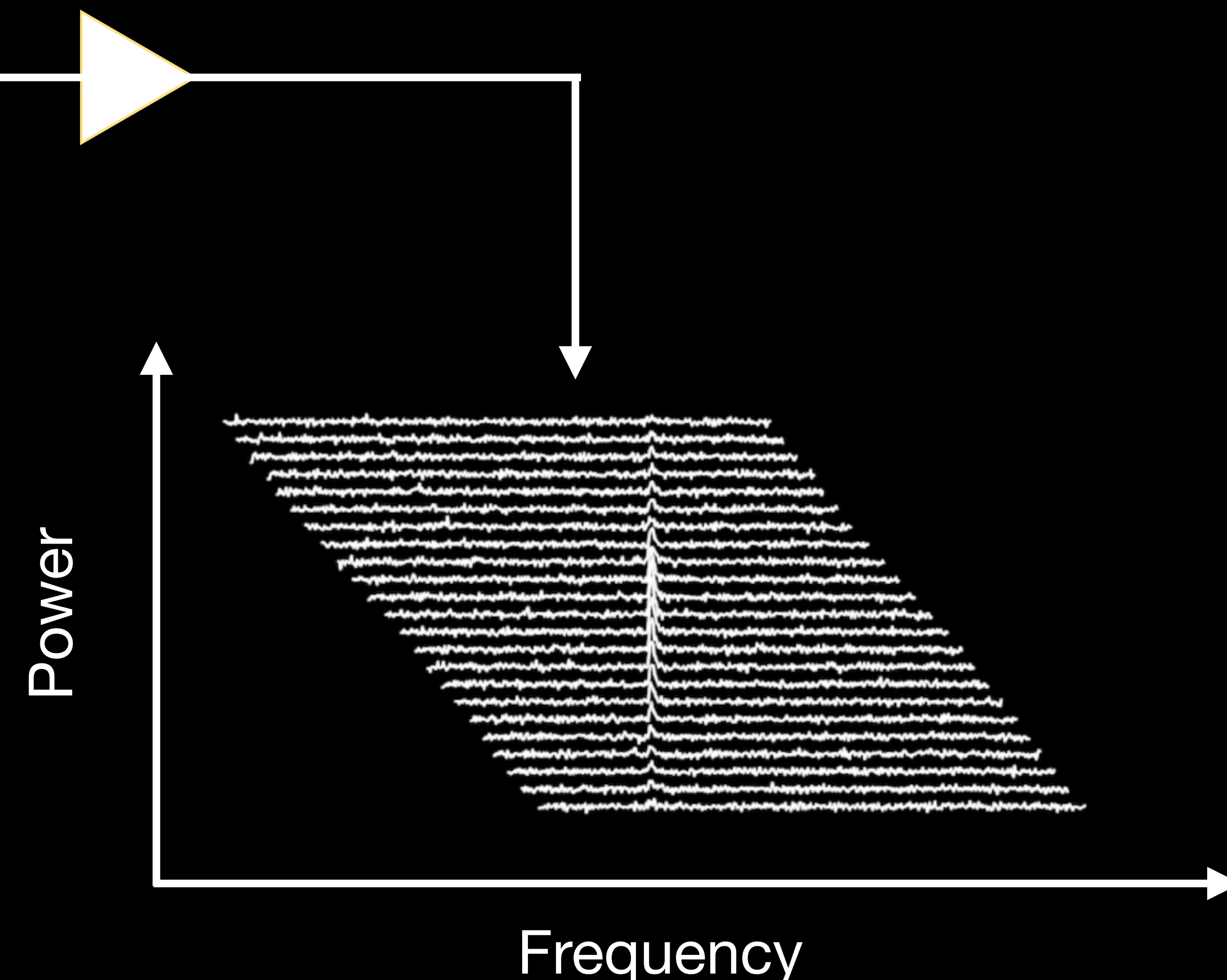
ADMX design (axion haloscope)

P. Sikivie, Phys. Rev. Lett. 51, 1415 (1983)

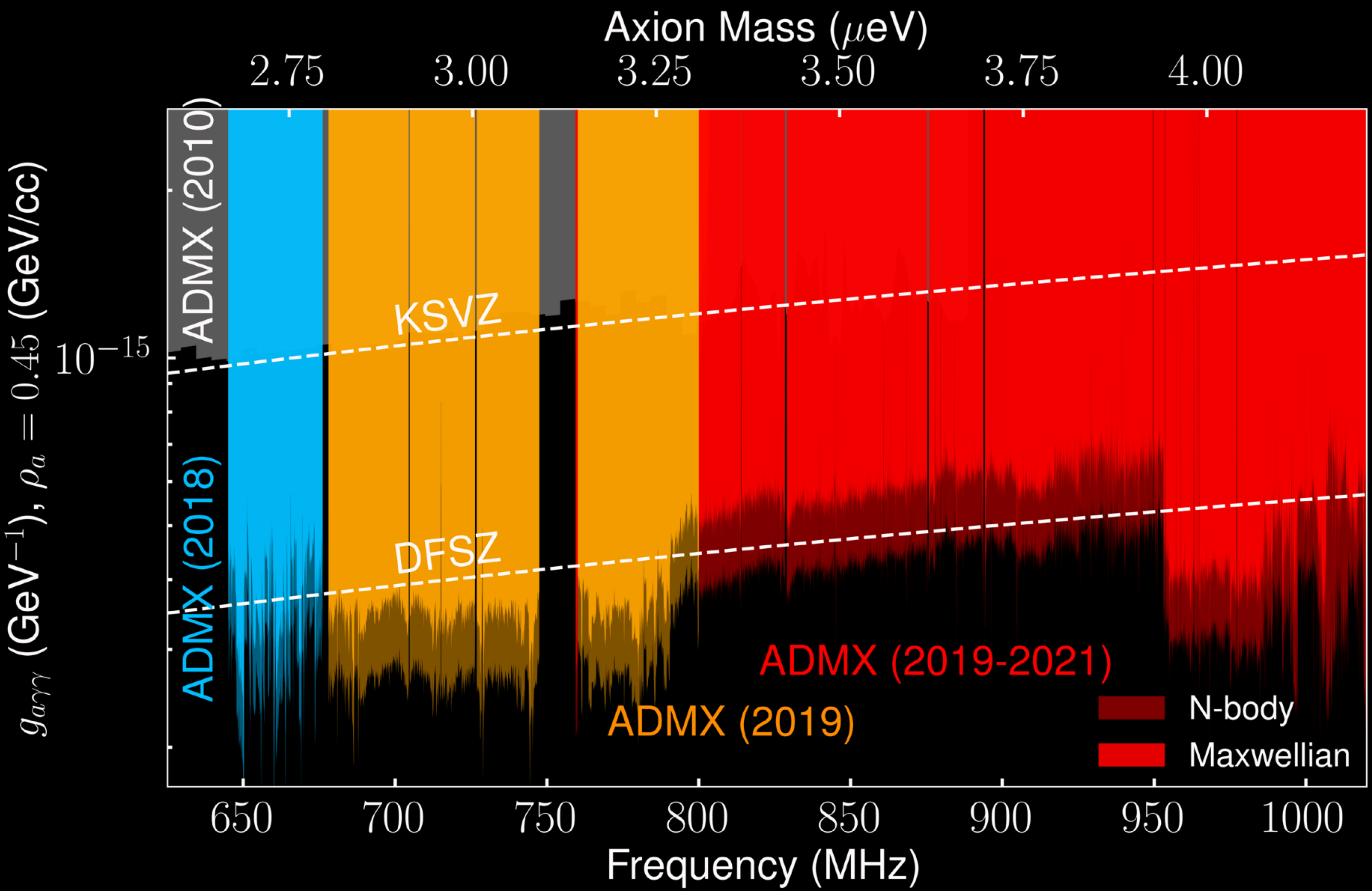
- Search on axion decay into photons: $g_{a\gamma\gamma}$
- Primary background: thermal noise





Benchmark models expected Axion ($\sim 1\ \mu$eV) power $\sim 10^{-23}$ Watts

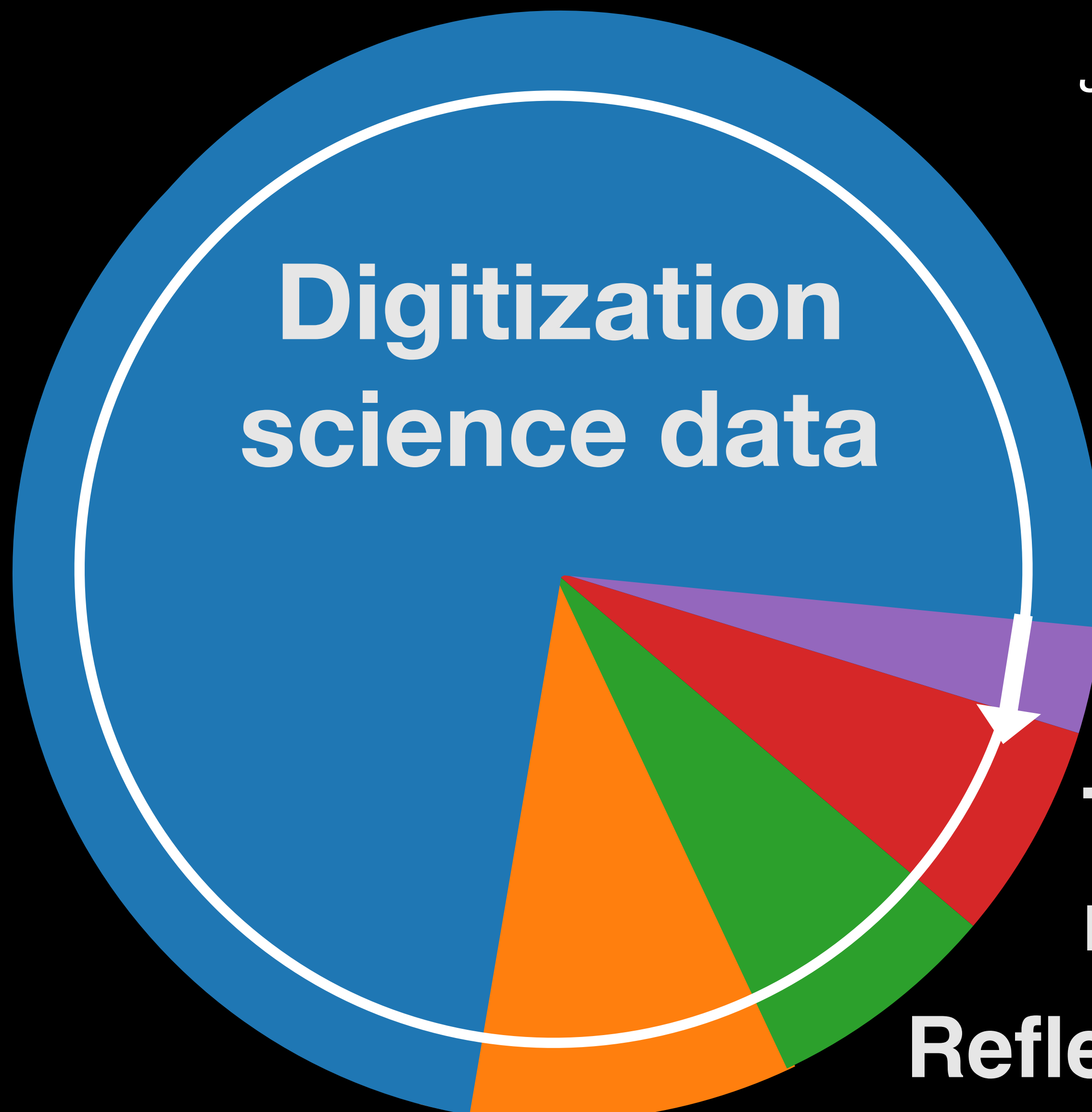
ADMX Gen 2-Run1: published data



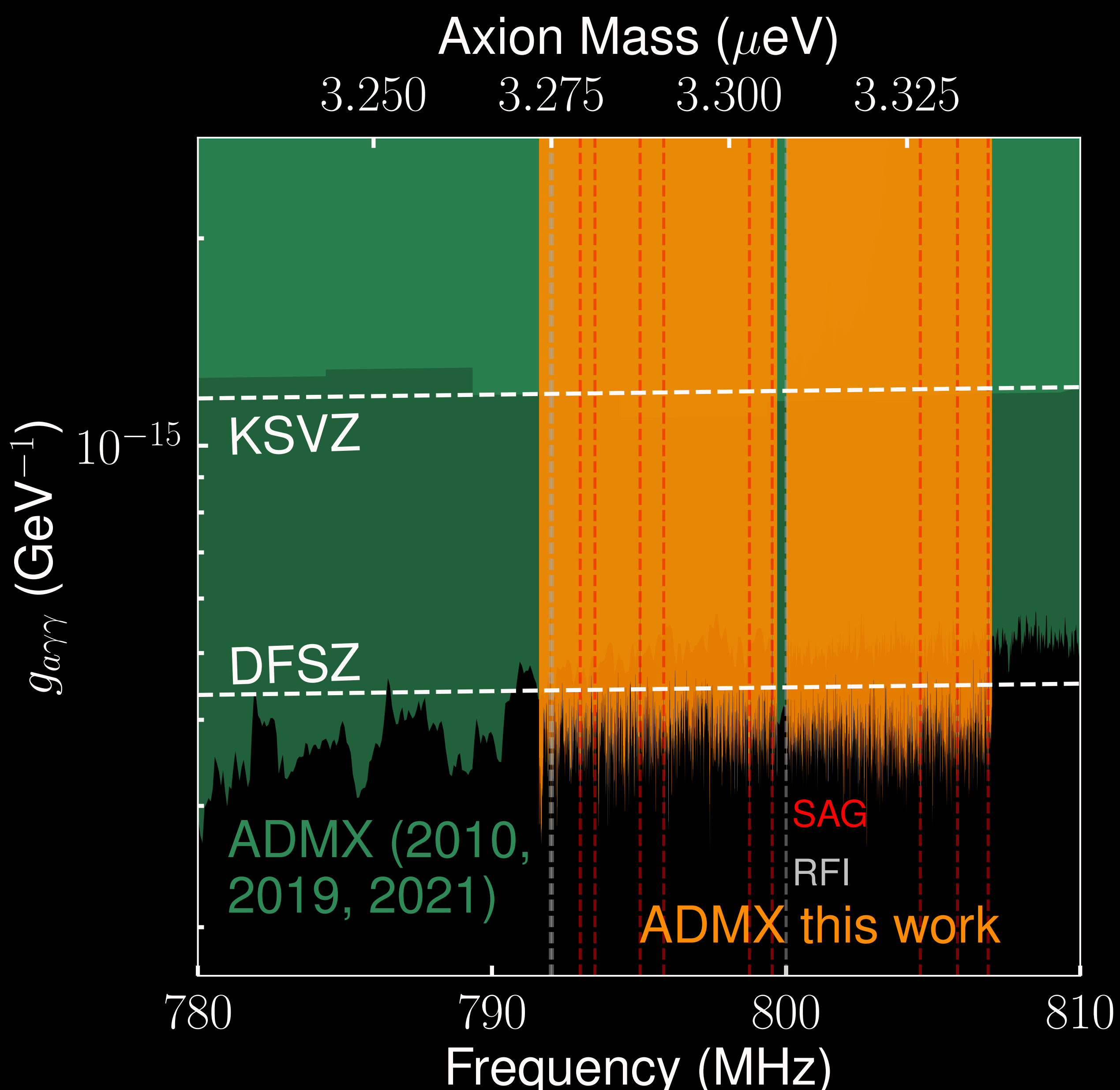
Fraction of operation time by task

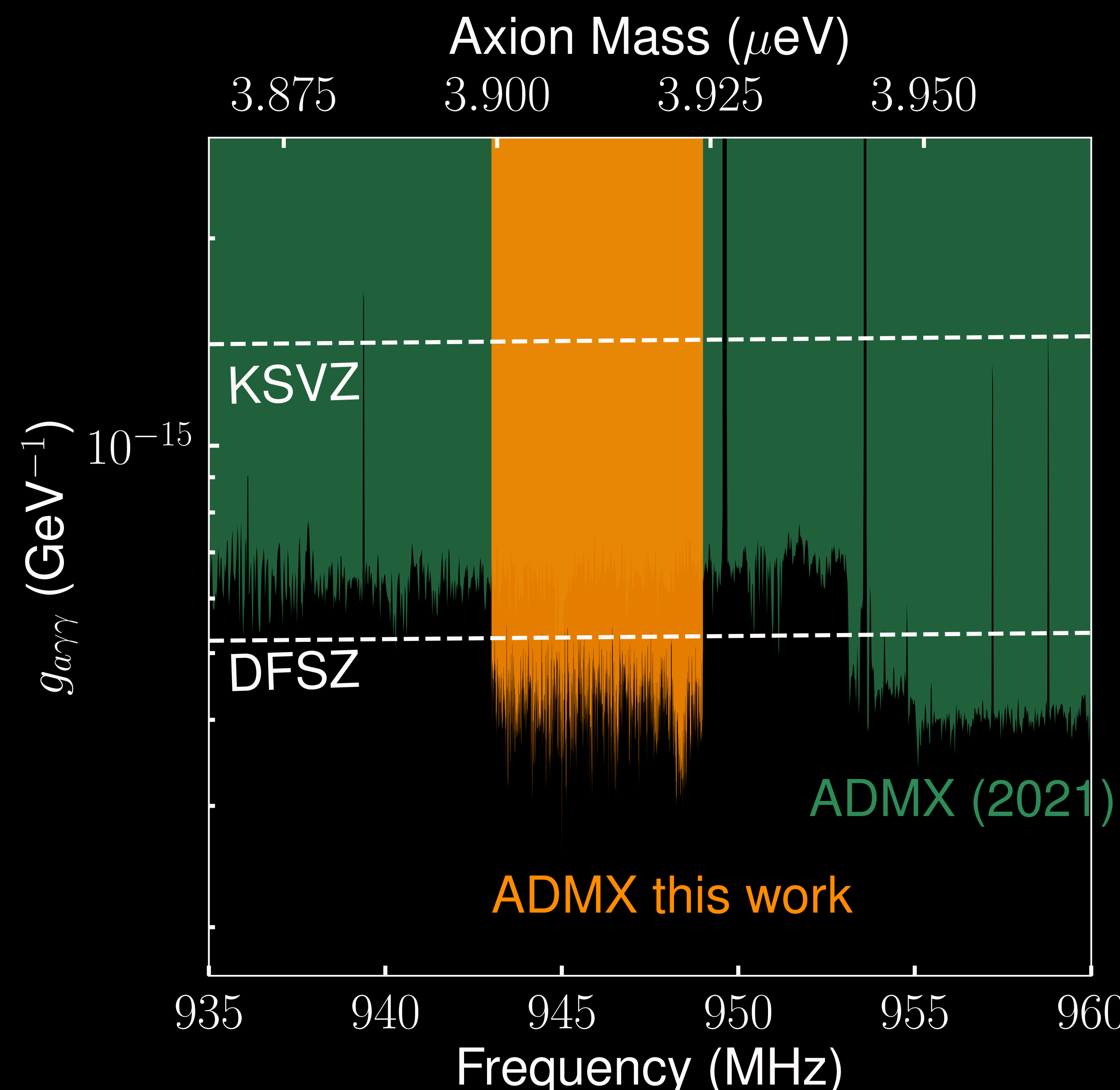
- 20 MHz in 5 months for DFSZ sensitivity

JPA: Josephson parametric amplifier



Preliminary sensitivity





SAG: synthetic axion generator
RFI: radio frequency interference

ADMX: Gen2 future plan 1

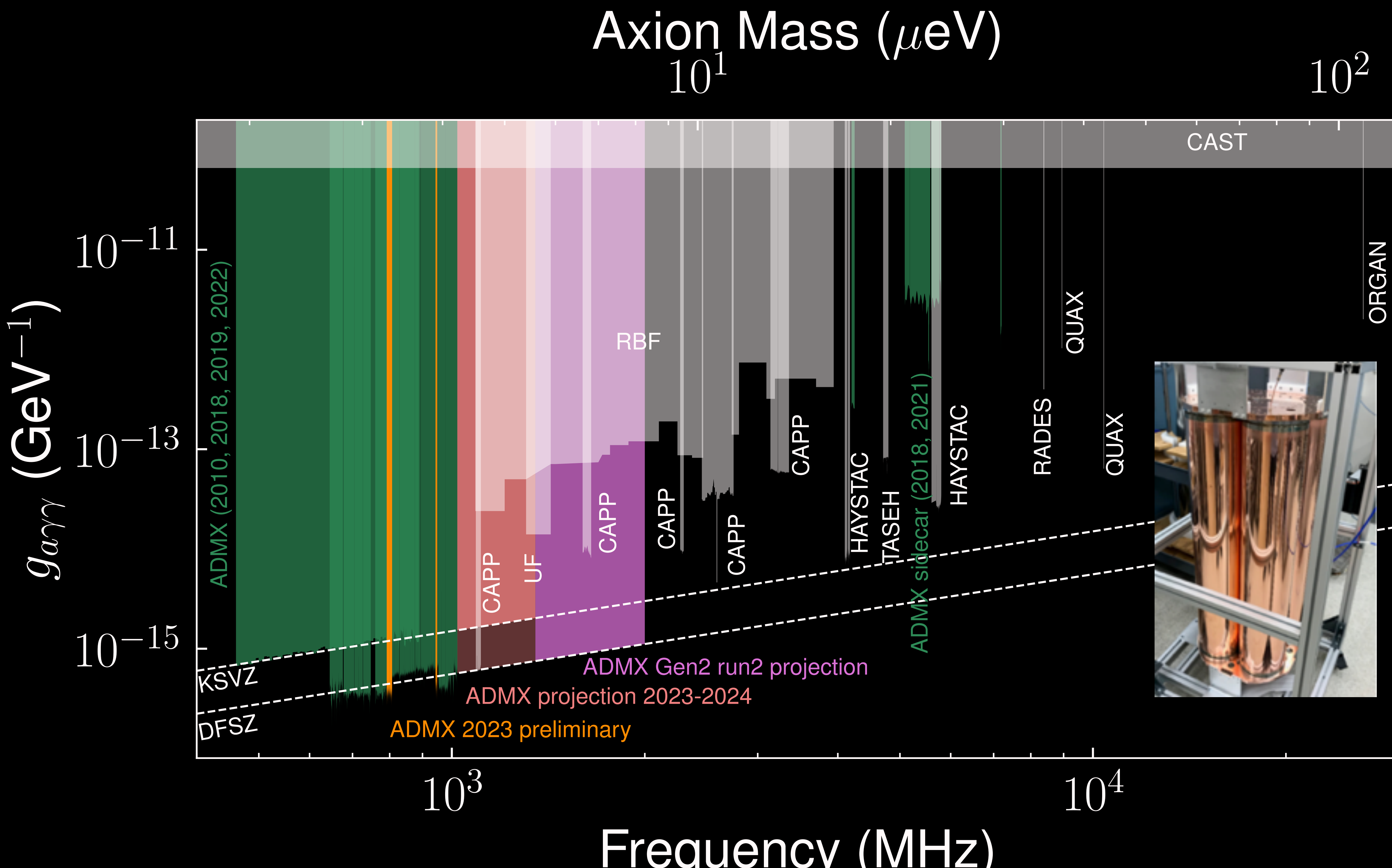
- Hardware upgrades on-going
- 1020 to 1350 MHz (plan to start this summer)

Cavity with
one bigger tuning rod

Cold electronics
including JPA

ADMX Gen2 future plan 2

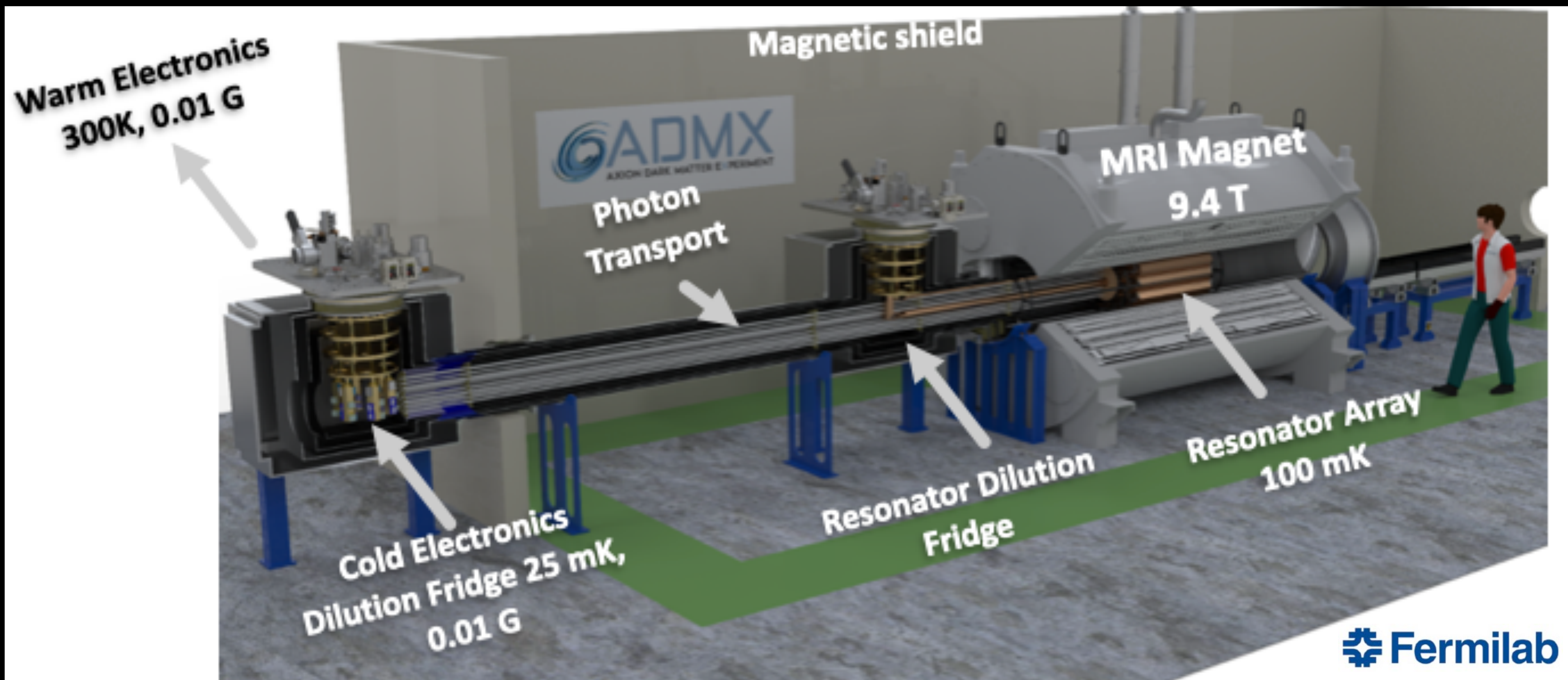
- Four-cavity array, up to 2 GHz



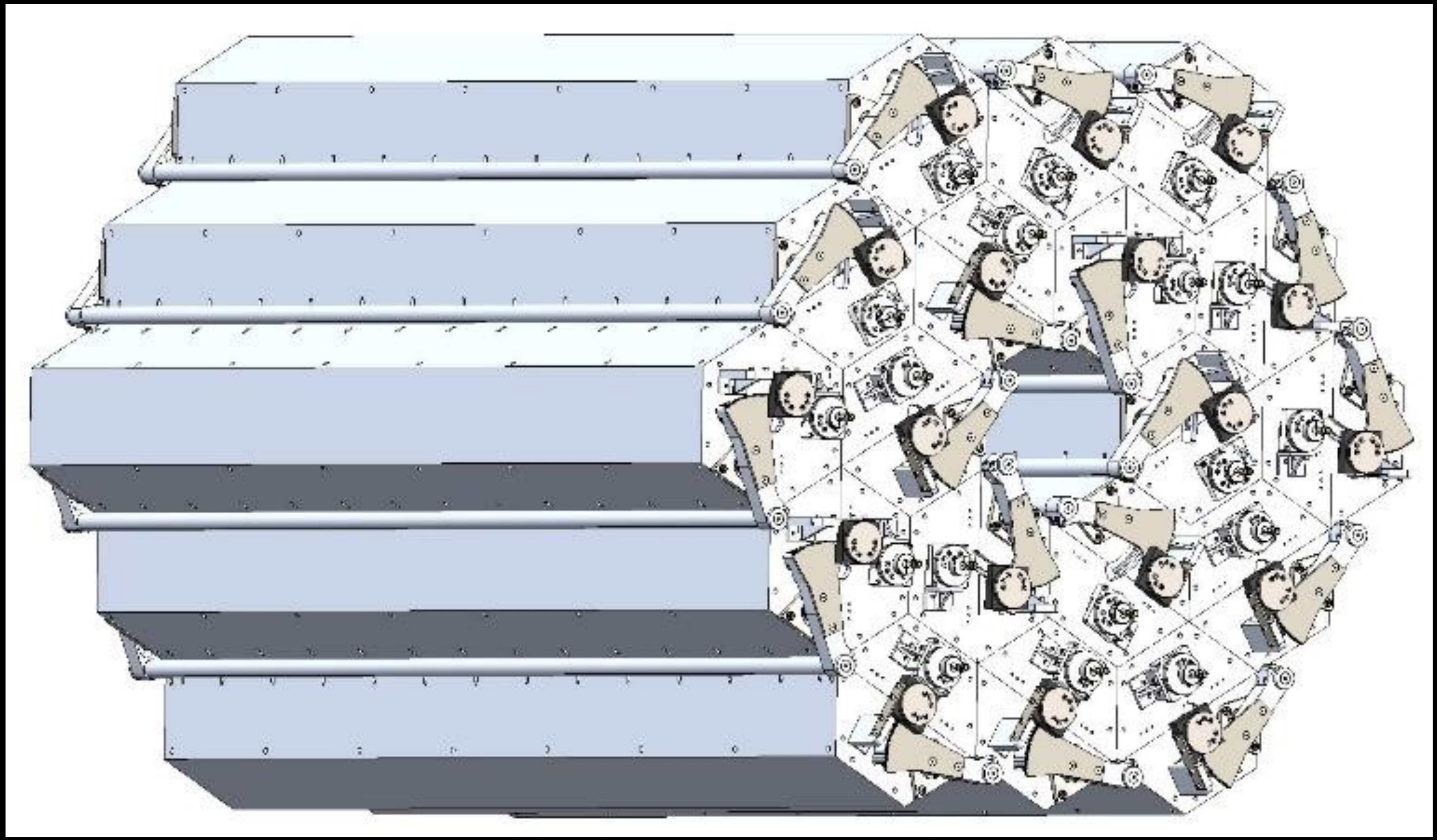
ADMX Extended Frequency Range (2–4 GHz)

MRI magnet
University of Illinois Chicago (UIC)
Manufactured by GE Healthcare in 2003

B≈ 9.4T ~ 80 cm **warm bore**



ADMX-EFR: More Cavities



- 18-cavity array
- 2-4 GHz

$V \sim 250$ L (almost doubled to now)

Scan speed [Hz/s]:
$\propto B^4 V^2 \sim \times 5$ of current ADMX

Conclusion

- Sensitivity has reached to the most promising QCD Axion benchmark model with quantum devices!
- ADMX future:
    - Search higher axion masses (near)
    - Even higher masses with multiple-cavity detectors (Gen2 and EFR)

Discovery could come at any time!

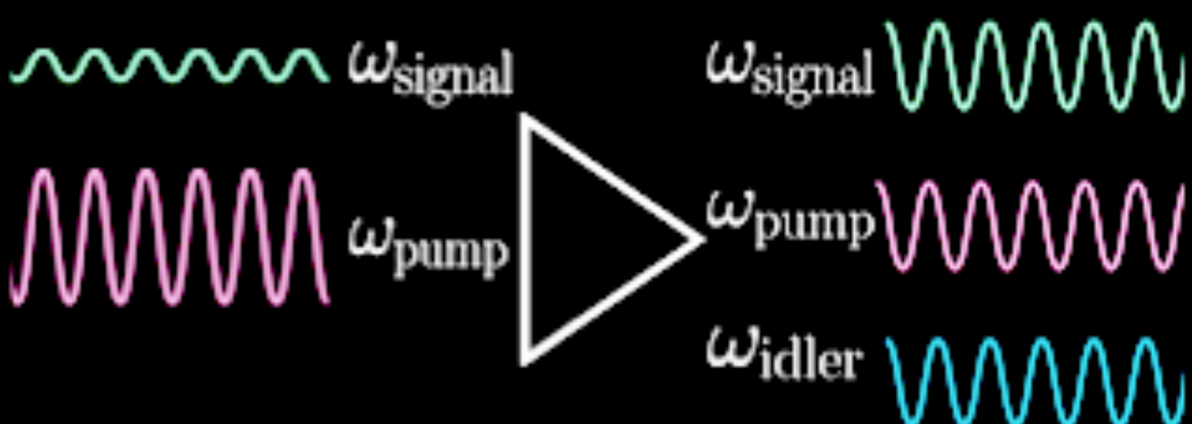
Backup

$$P_{\text{axion}} = 7.7 \times 10^{-23}\ \text{W} \left(\frac{V}{136\ \ell}\right)\left(\frac{B}{7.5\ \text{T}}\right)^2\left(\frac{C}{0.4}\right) \times$$

$$\left(\frac{g_\gamma}{0.36}\right)^2\left(\frac{\rho_a}{0.45\ \text{GeV/cc}}\right)\left(\frac{f}{1\ \text{GHz}}\right)\left(\frac{Q_L}{80{,}000}\right).$$

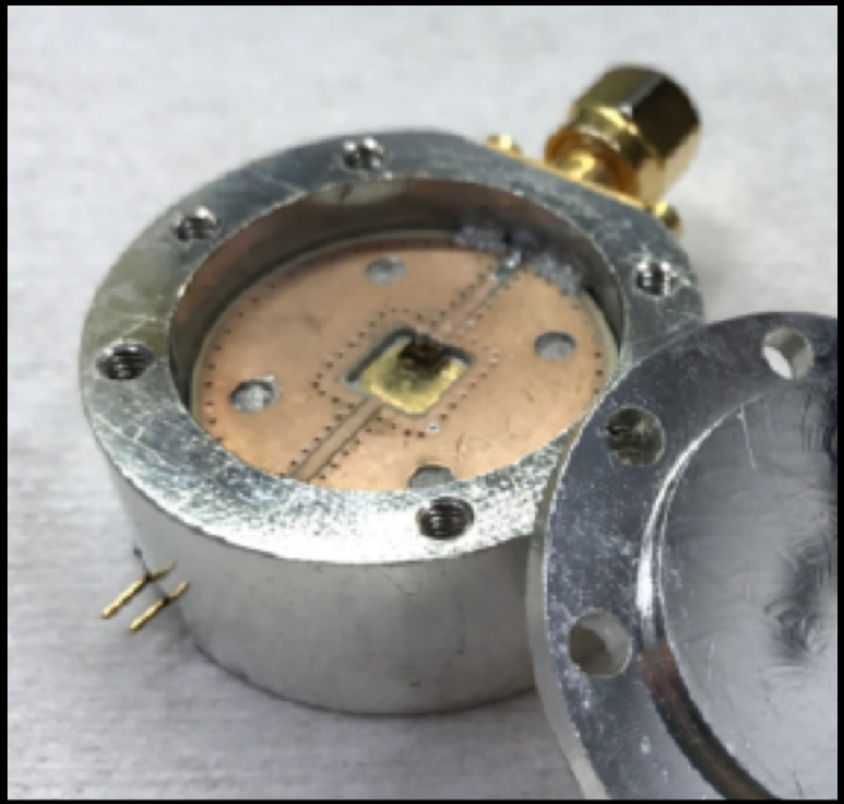
ADMX Gen2 with quantum amplifiers

- Josephson Parametric Amplifiers (JPAs)
  - Ideal for higher frequency range searches (current main)
  - Narrowband gain



Figures courtesy of Shahid Jawas

$$N_{tot} = N(T_{sig}, \omega_{signal}) + N(T_{idler}, \omega_{idler})$$



JPA provided by
Siddiq Group at UC Berkeley

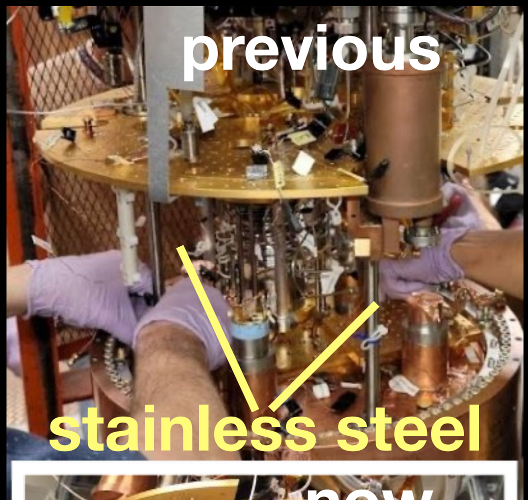
Noise temperature

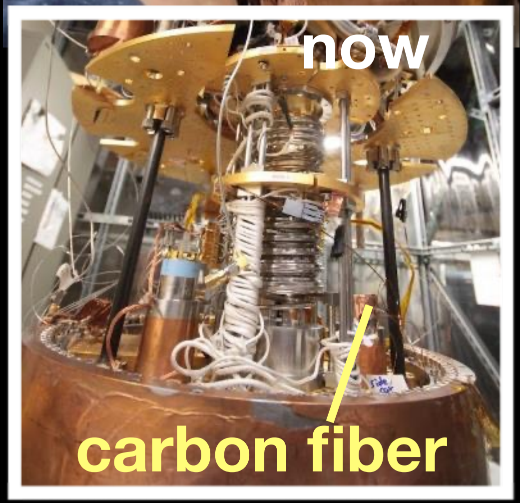
- Low noise receiver
  - JPA (T_{signal} 140mK, T_{idler} 100mK) + Heterostructure Field Effect Transistor (HFET) amp (4K) + Post-amp (RT)

Heat flow: 70 ->12μW

T_{phy}: 150 -> 100 mK

1GHz~50mK (standard quantum limit)





More than 100 mK improvement in T_{sys} reached

$$\mathrm{SNR} = \frac{P_{\mathrm{axion}}}{\sigma} = \frac{P_{\mathrm{axion}}}{k_B T_{\mathrm{sys}}} \sqrt{\frac{t}{b}},$$

$$T_{\mathrm{sys}} = \frac{T_{\mathrm{HFET}}/\epsilon}{\mathrm{SNRI}}$$

in-situ

$$\mathrm{SNRI} = \frac{\mathrm{G_{on}}}{\mathrm{G_{off}}} \frac{\mathrm{P_{off}}}{\mathrm{P_{on}}},$$