Status report on the ADMX and QSHS instruments

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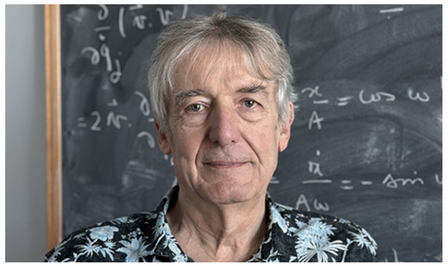
Paris-Saclay Astroparticle Symposium

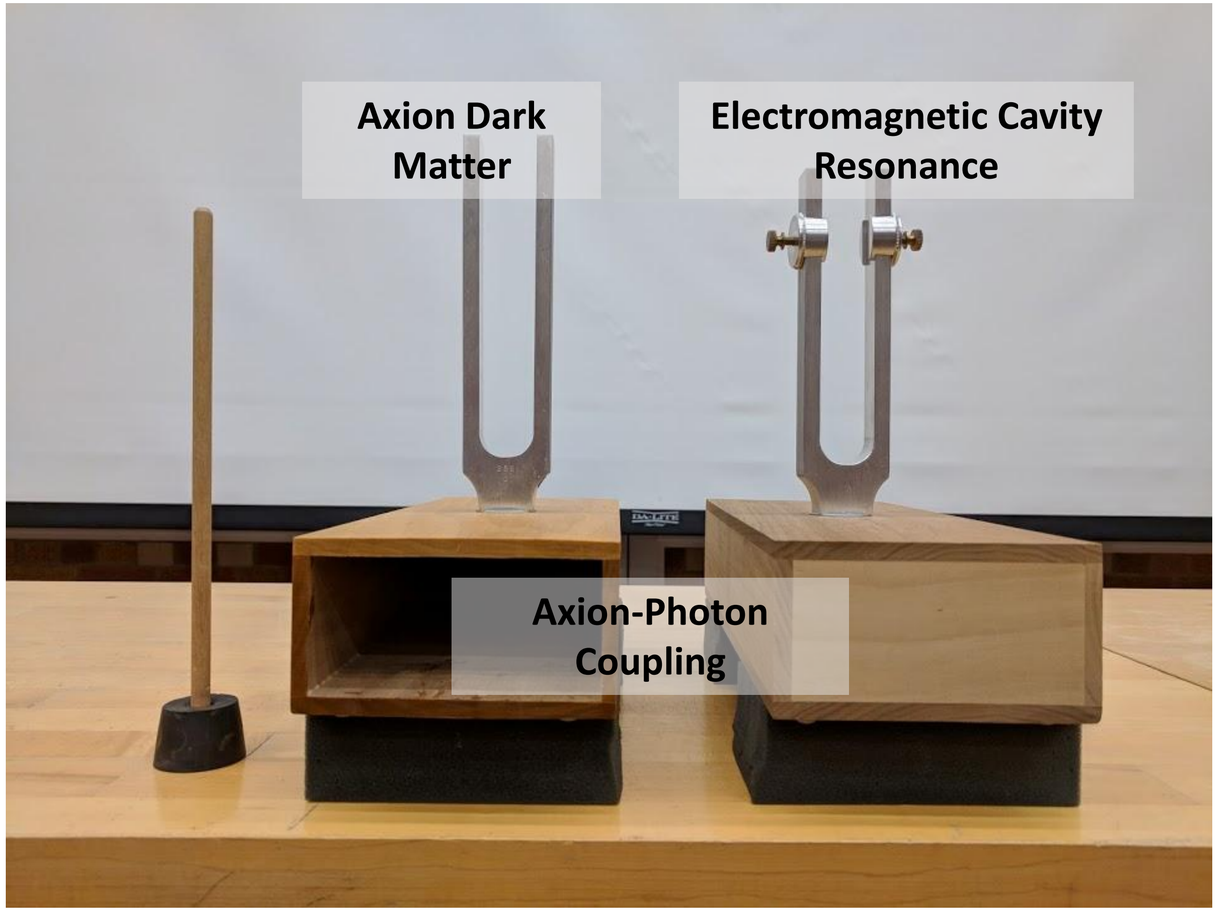
6th November 2025

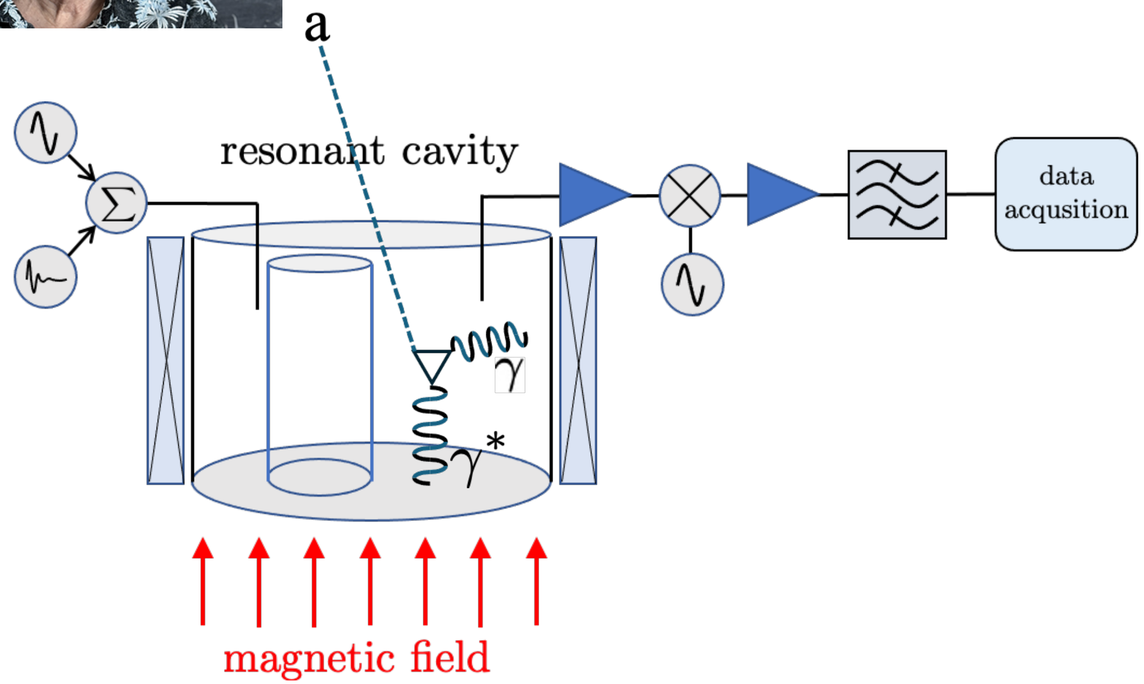
on behalf of the QSHS and ADMX collaborations.

QSHS groups:

Resonant Axion Haloscopes

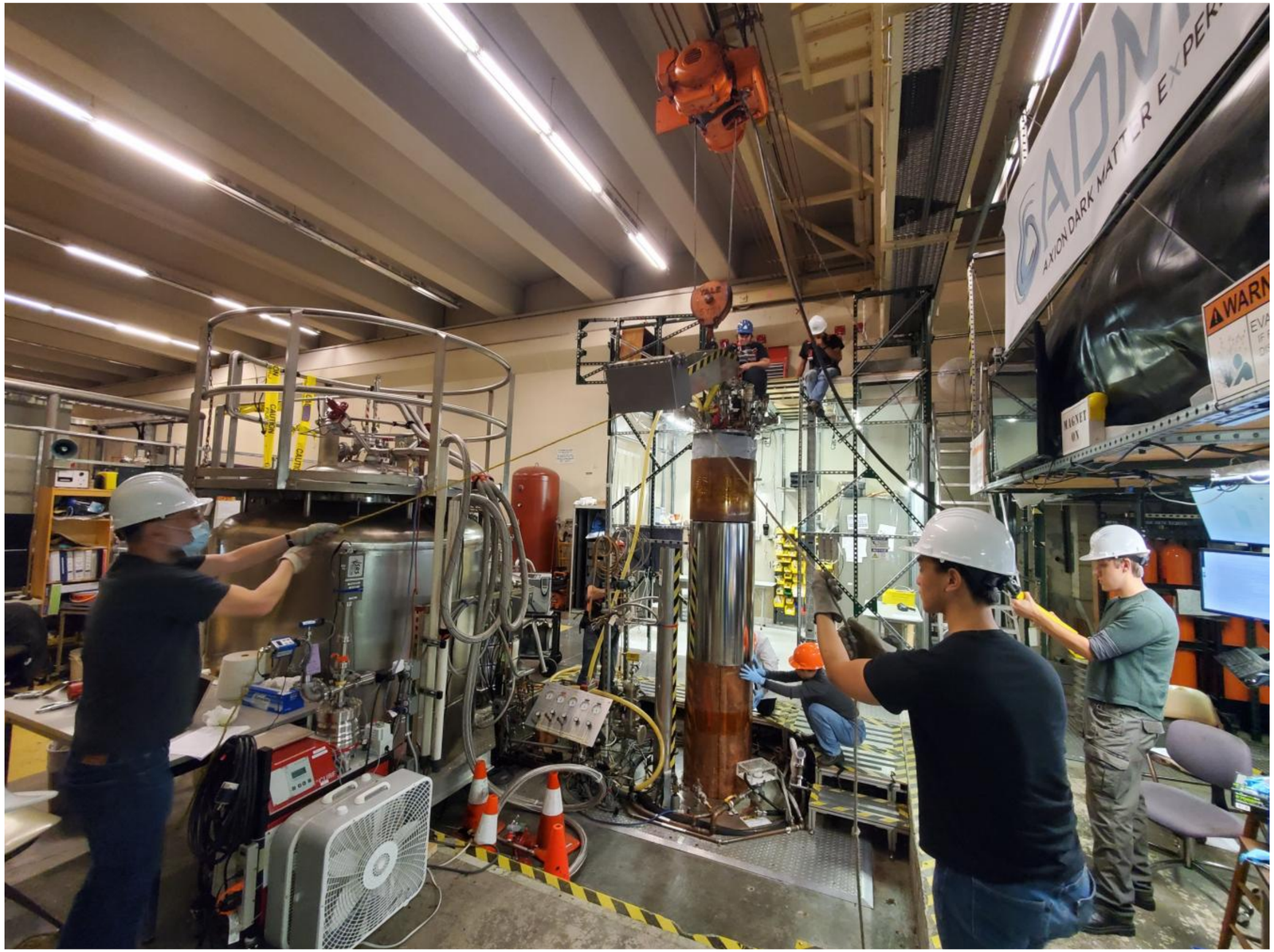




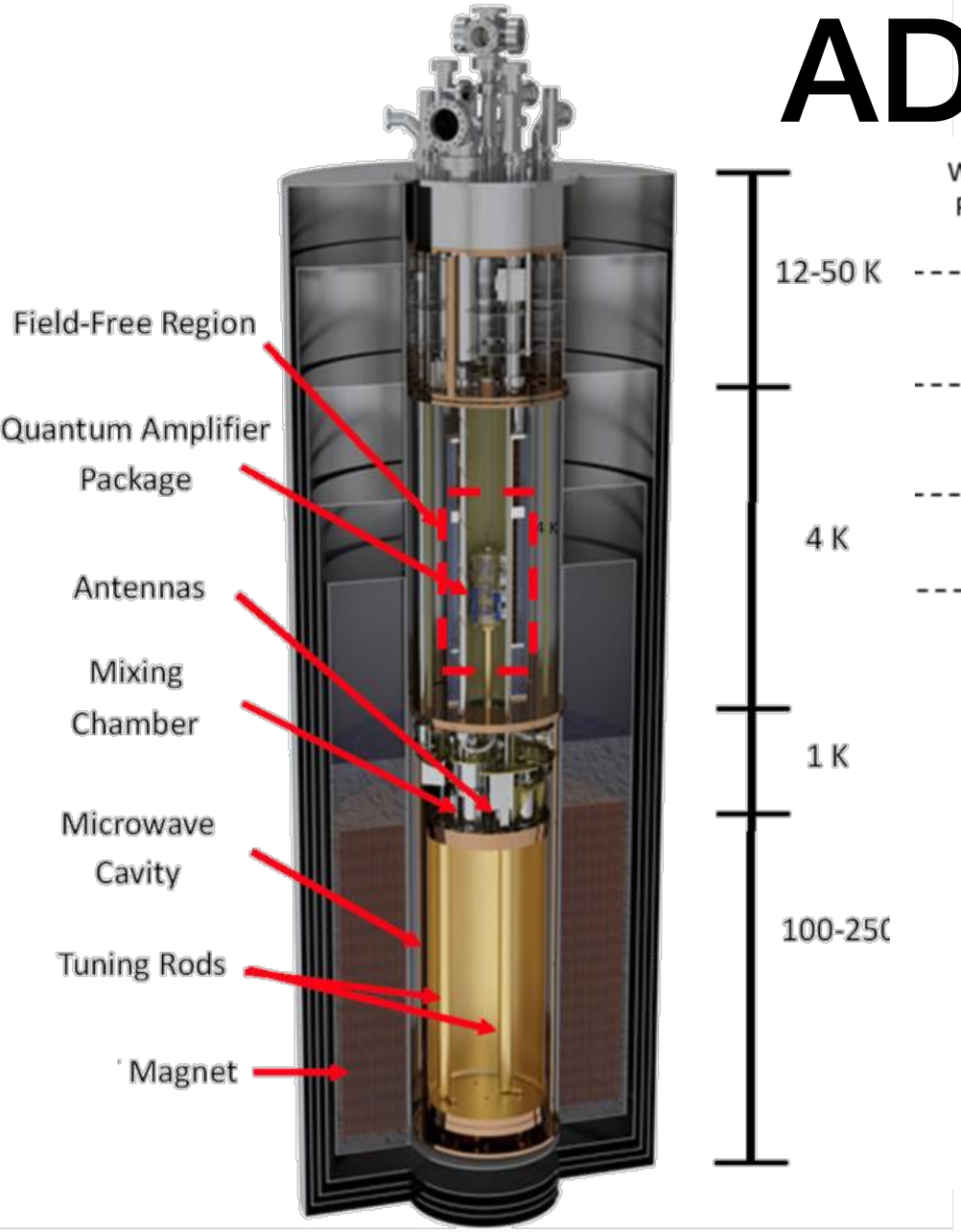


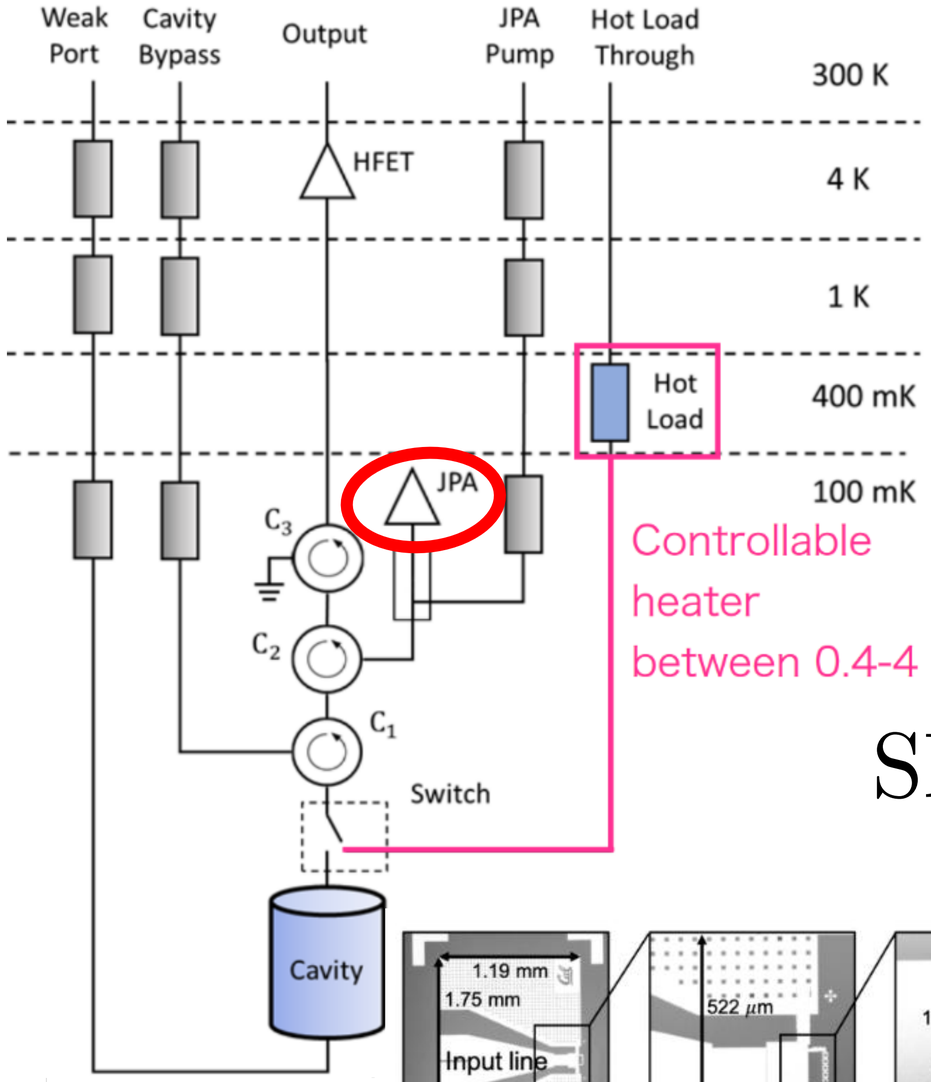
- Power boosted by a factor of Q for axions resonating in a cavity TM mode.
- Require axions to be dark matter, and present locally.
- Tuned experiment, slowing the search.
- Only method so far to achieve sensitivity to QCD axions.

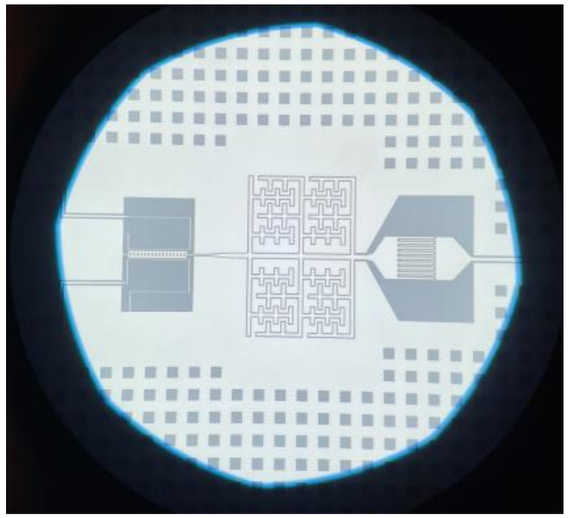
ADMX



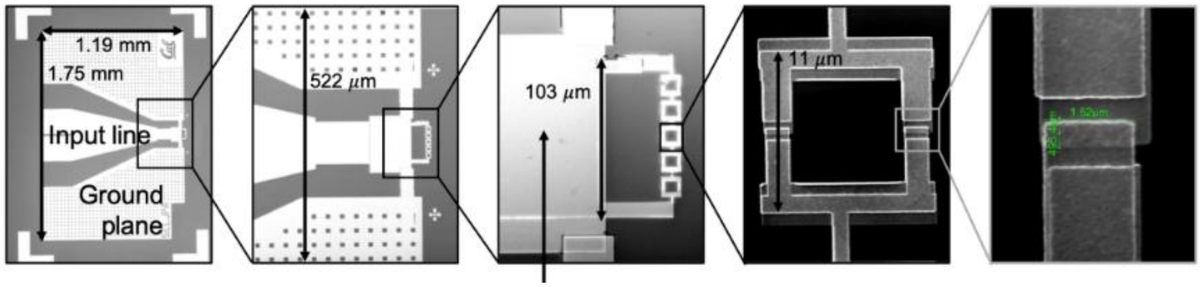
ADMX design





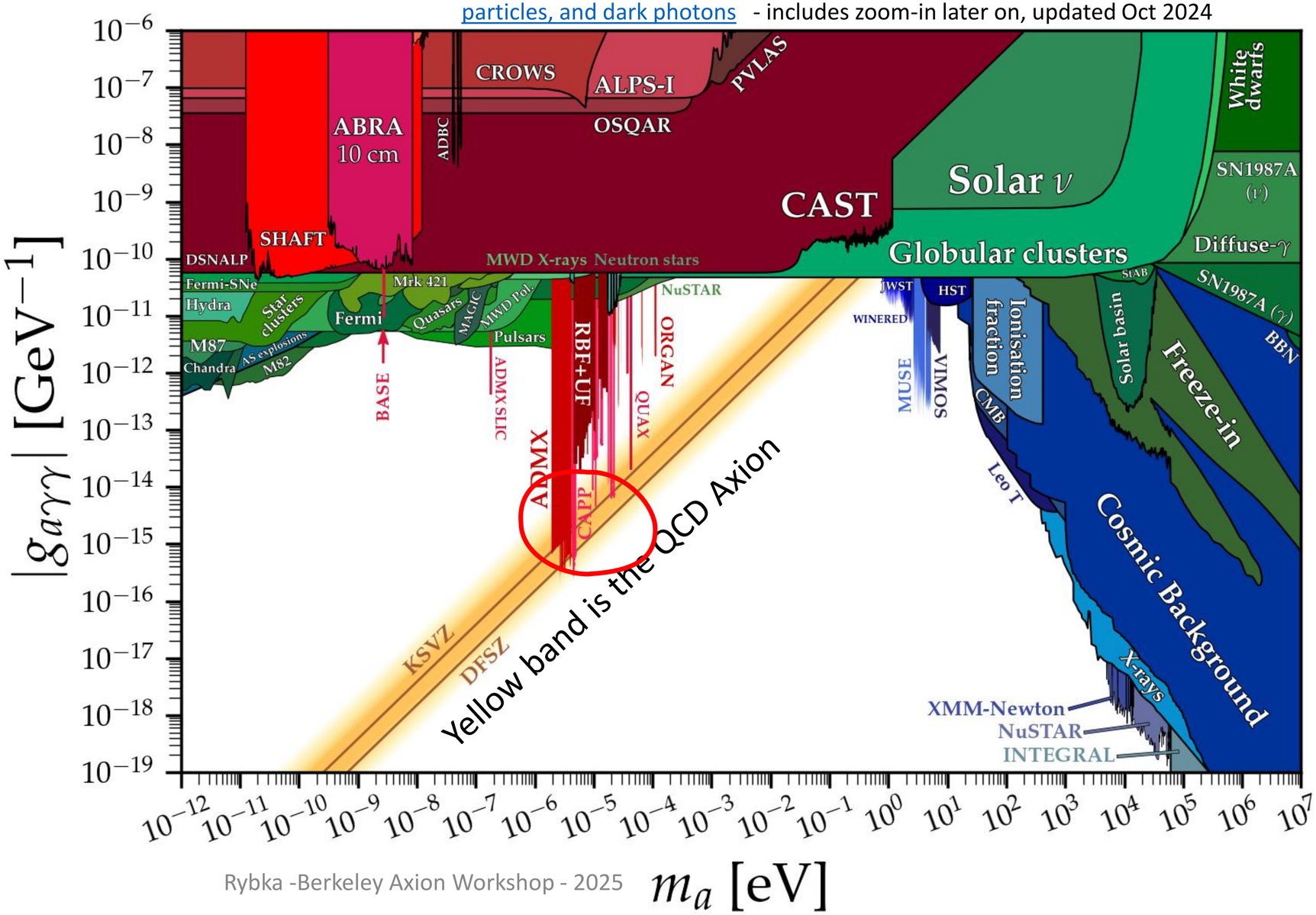


$$\mathrm{SNR} = \frac{P_s}{P_n}\sqrt{Bt}$$



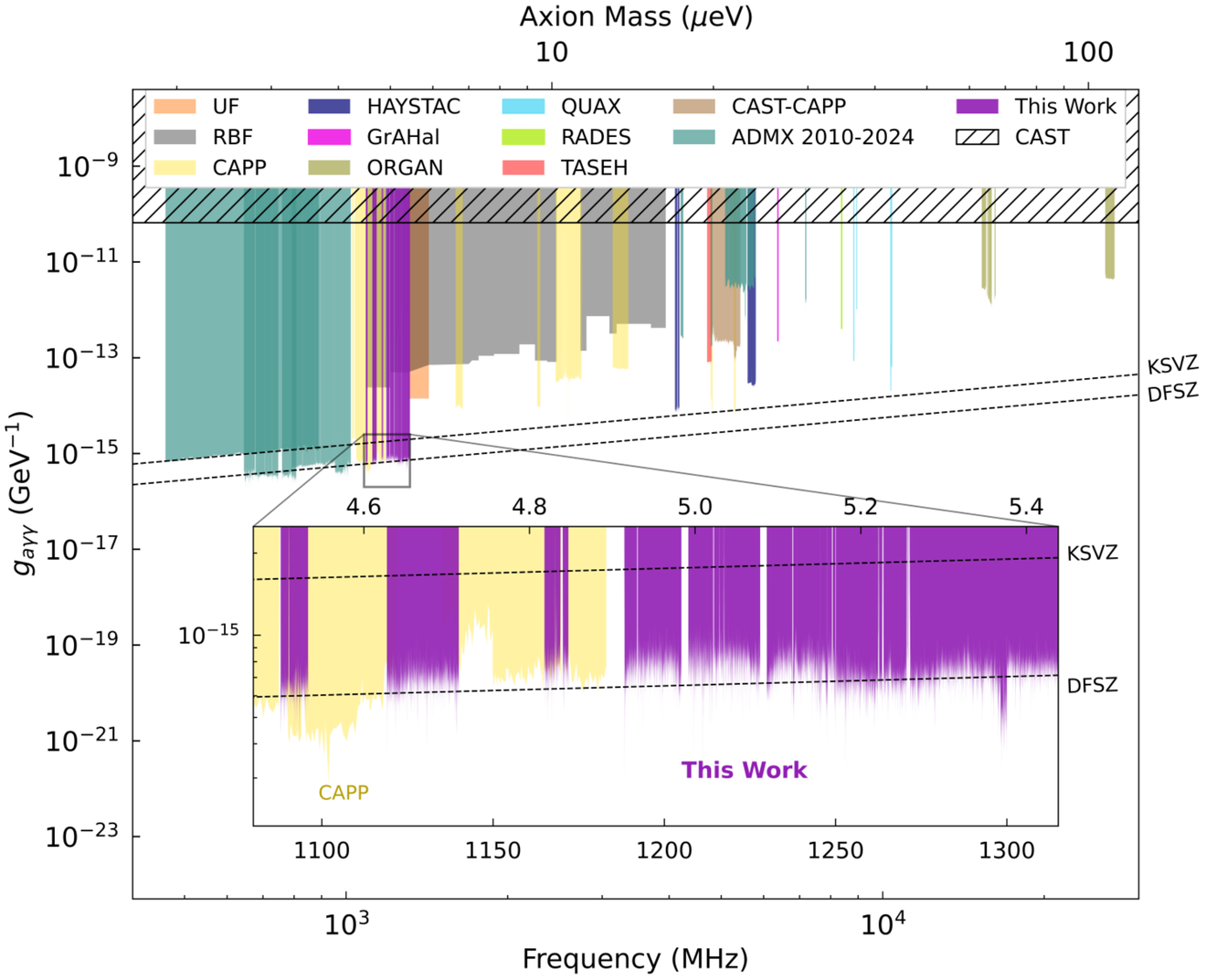
QCD AXION / ALP landscape

GitHub - cajohare/AxionLimits: Data, plots and code for constraints on axions, axion-like particles, and dark photons - includes zoom-in later on, updated Oct 2024



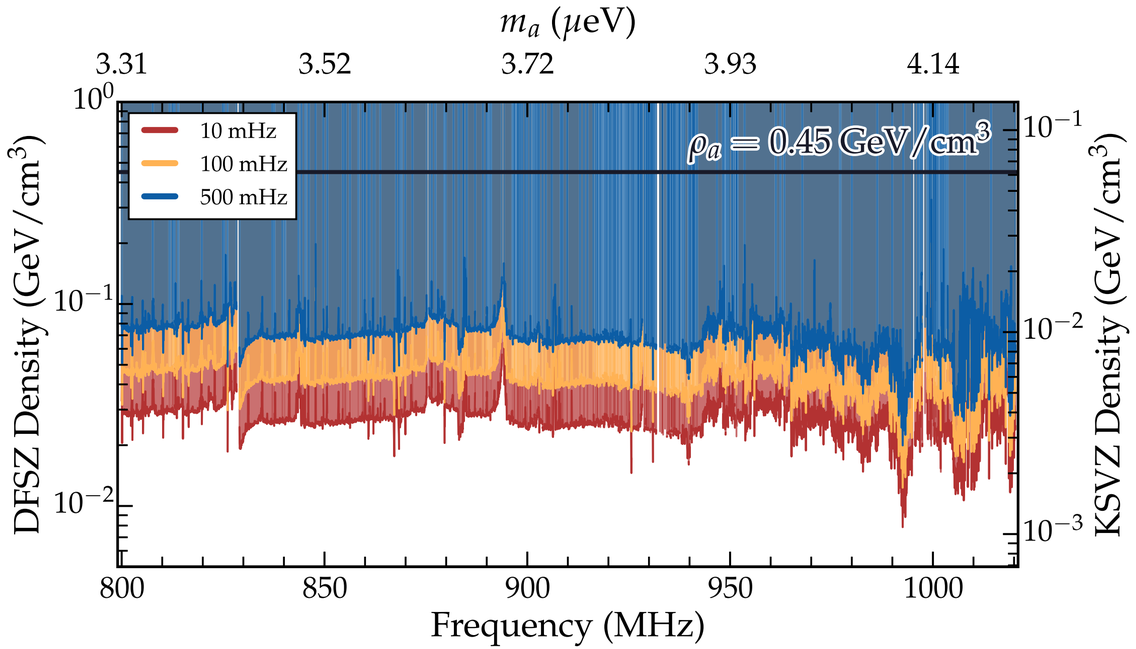
Recent ADMX results

Limits assuming 0.45GeV/cc halo density, thermalised halo



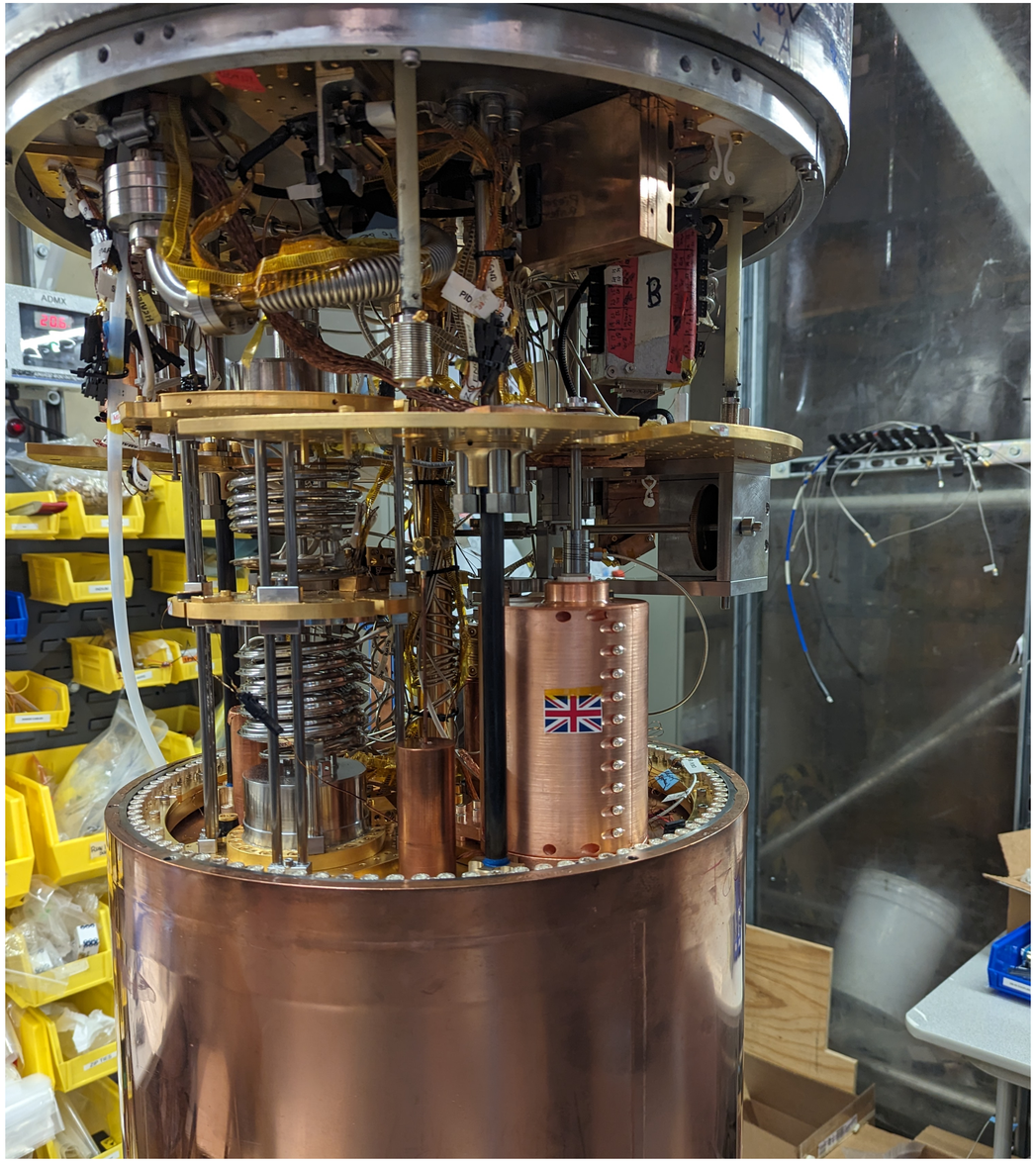
https://arxiv.org/abs/2504.07279

Limits assuming non-thermalised axions assuming three different signal bandwidths



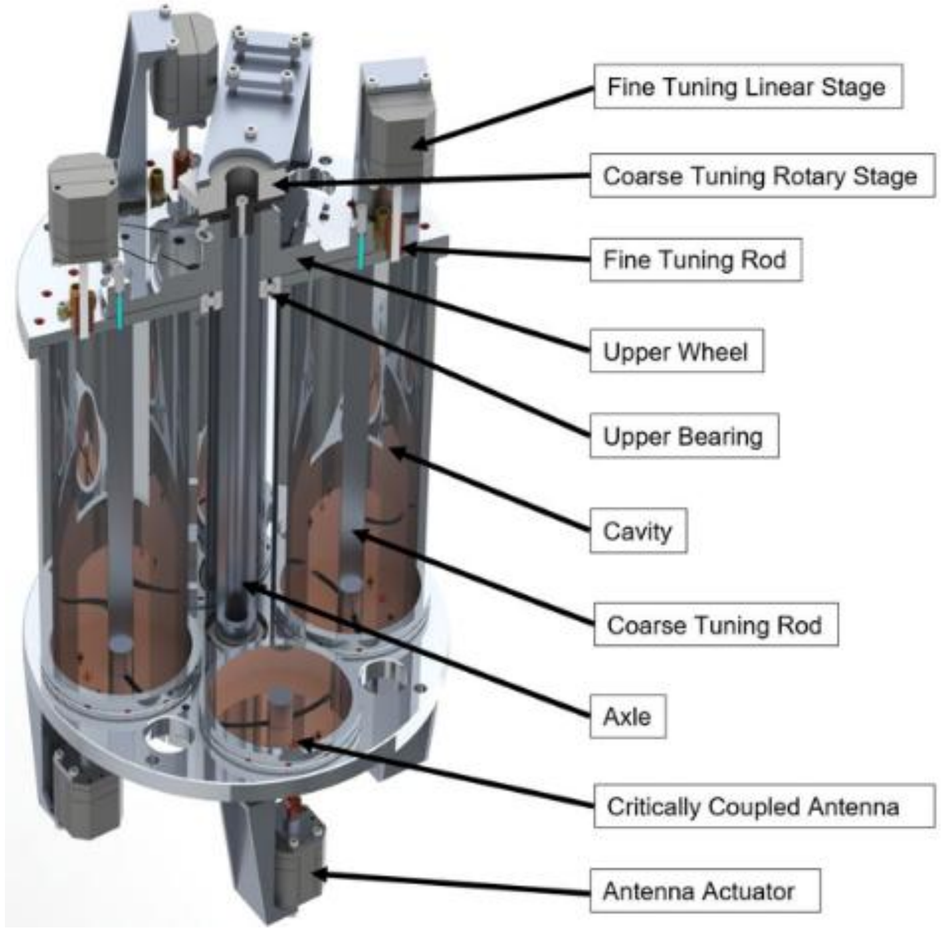
PHYS. REV. D **112,** L101101 (2025)

ADMX sidecar



- A smaller cavity mounted on top of the main ADMX 1 cavity
- Large tuning rod, potentially tunable from 4 to 8GHz (17 to 34 micro eV)
- Small volume, but useful for testing RF electronics due to tuning range.
- QSHS manufactured and delivered the current operational ADMX sidecar cavity, alongside a copper and an aluminium copy for use by QSHS.
- Some ongoing issues with sidecar tuning and coupling to antennas need investigating. One job for QSHS.

ADMX 4-cavity array

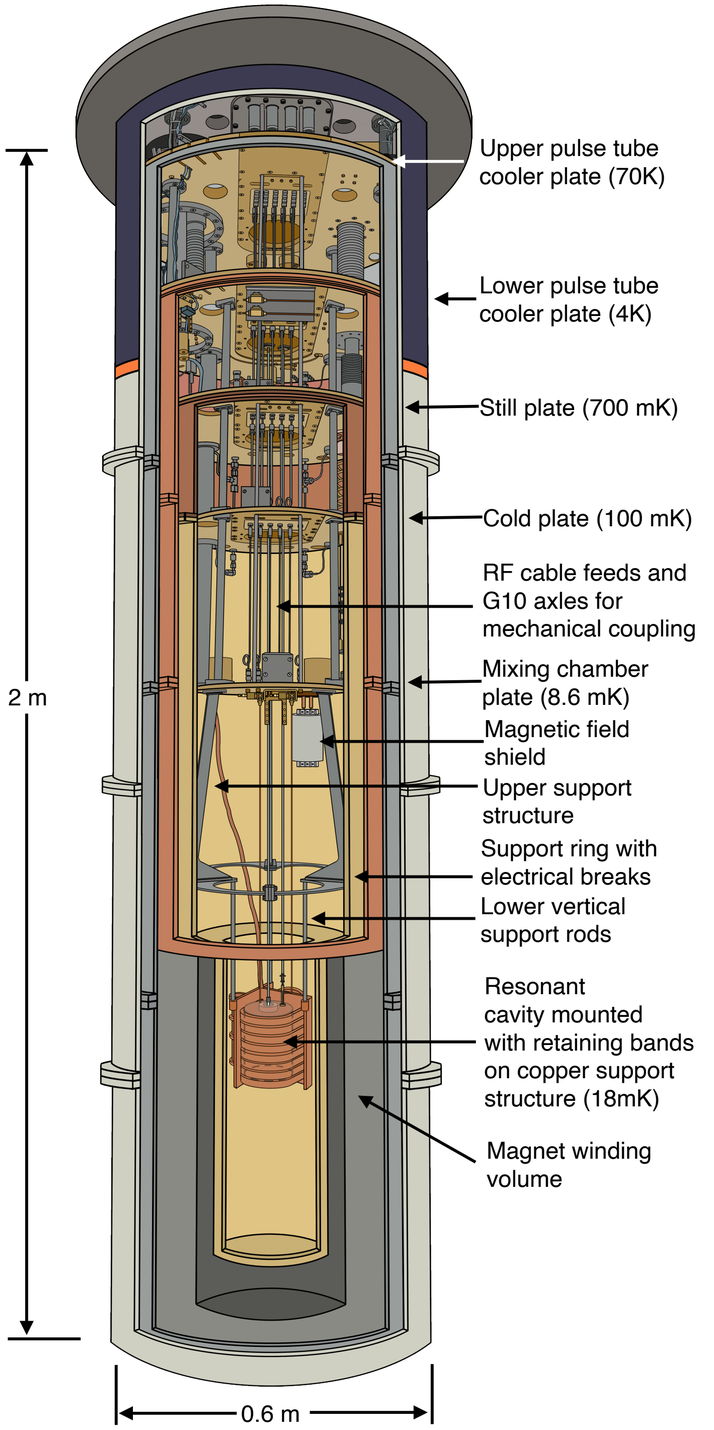


- Four cavities power combined in phase.
- Mode frequencies must match.
- Stepper motor drives for sufficient torque, cryogenic gear reduction for control.
- Installation and commissioning to start in 2026.

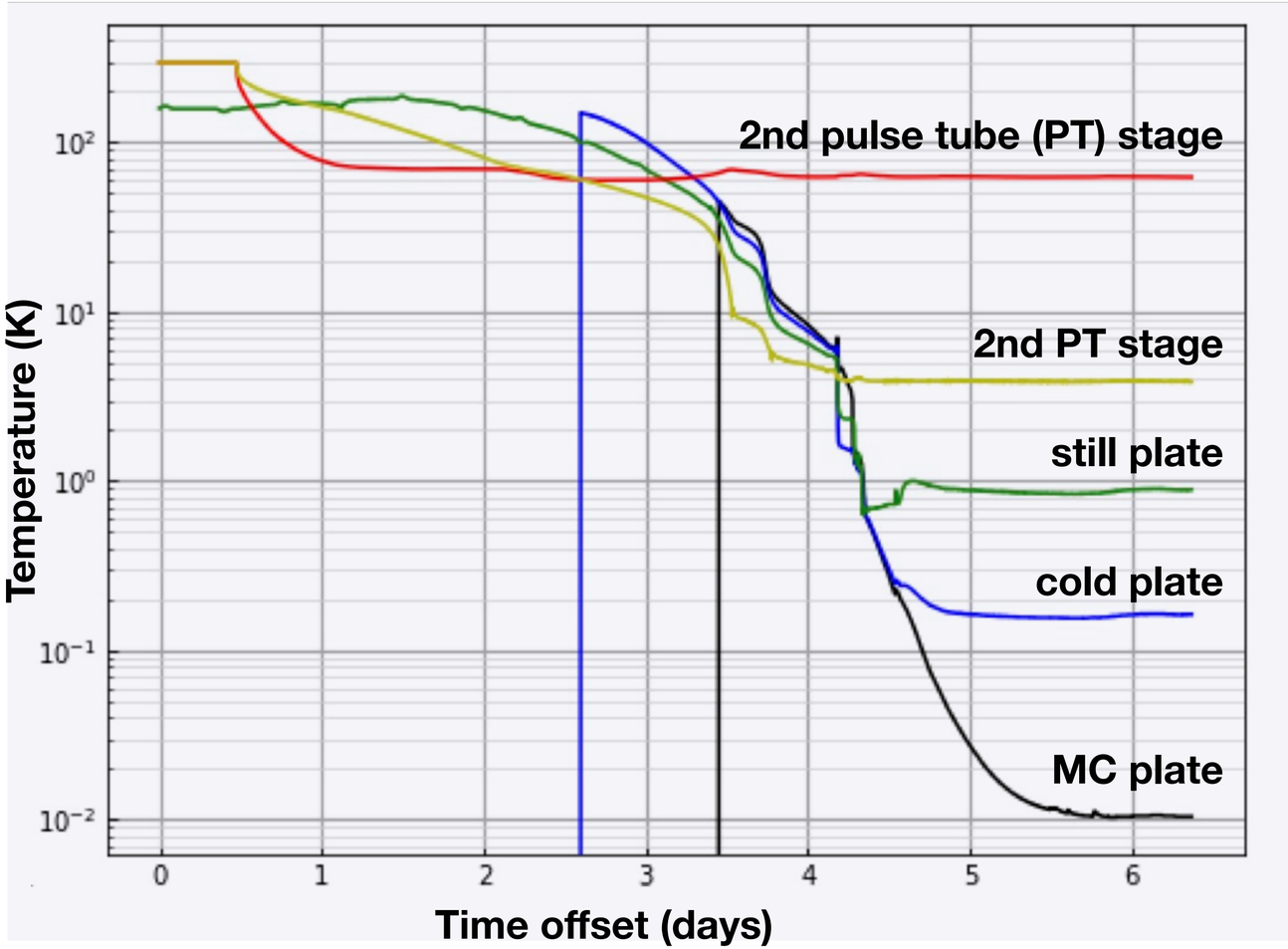
Quantum Sensors for the Hidden Sector

UK collaboration funded by STFC in 2021 to develop low noise quantum electronics for application to axion searches. Works with ADMX.

QSHS design



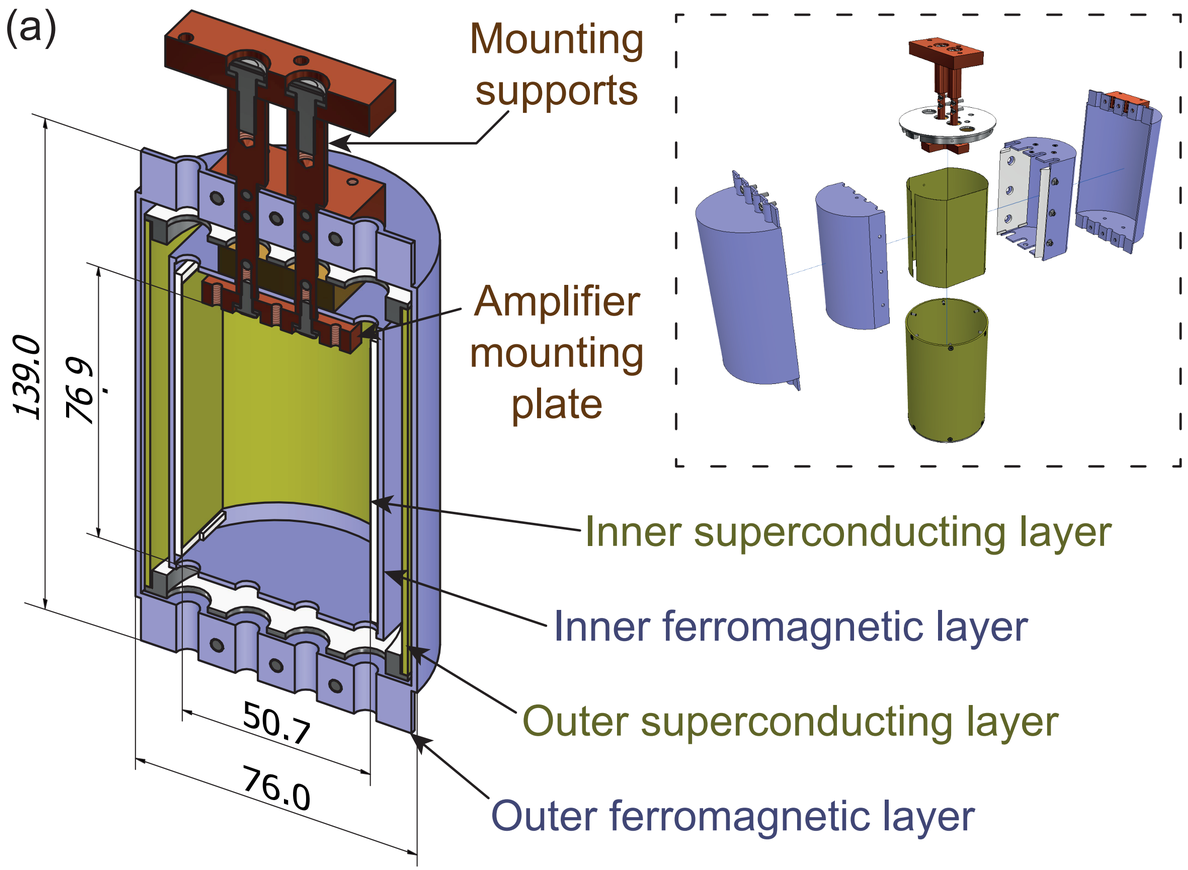
- **Oxford Instruments Proteox MX**
- **Dry closed cycle system.**
- **8T shielded 19cm bore magnet.**
- **40cm diameter low field (<20 gauss) bay above magnet bore.**
- **Two stage pulse tube precooler for magnet, motor drives, HFET amplifiers, dilution fridge.**
- **Copper sidecar resonant cavity hung from mixing chamber plate by a three leg stainless steel support structure.**
- **Insulation breaks in large metal loops for some quench protection.**

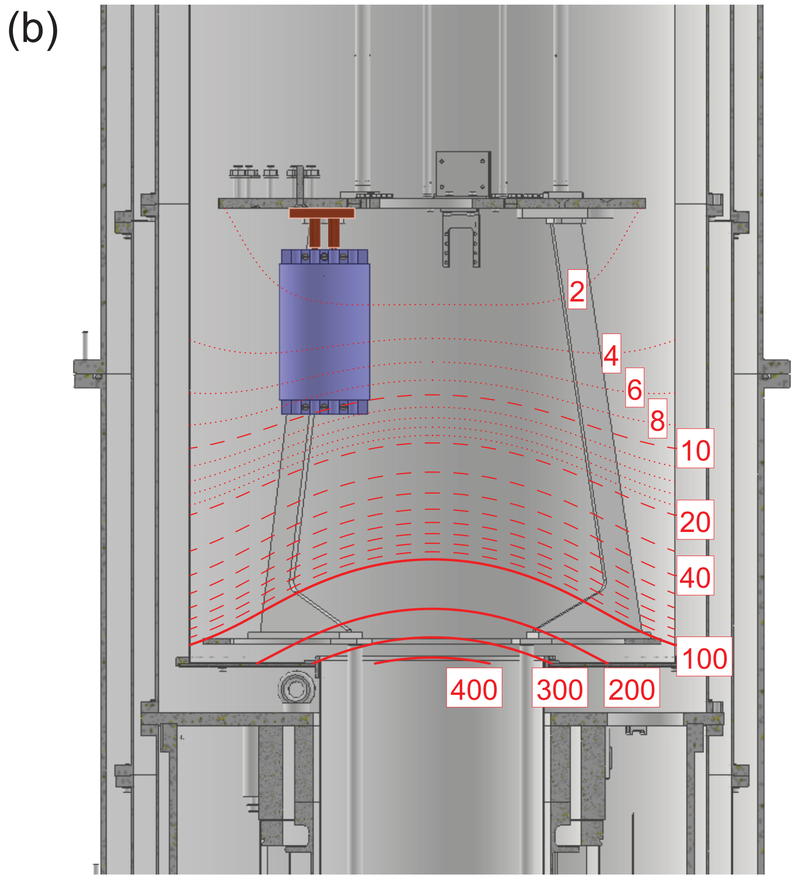


Empty cavity (no tuning rod) cooled to 18.5mK

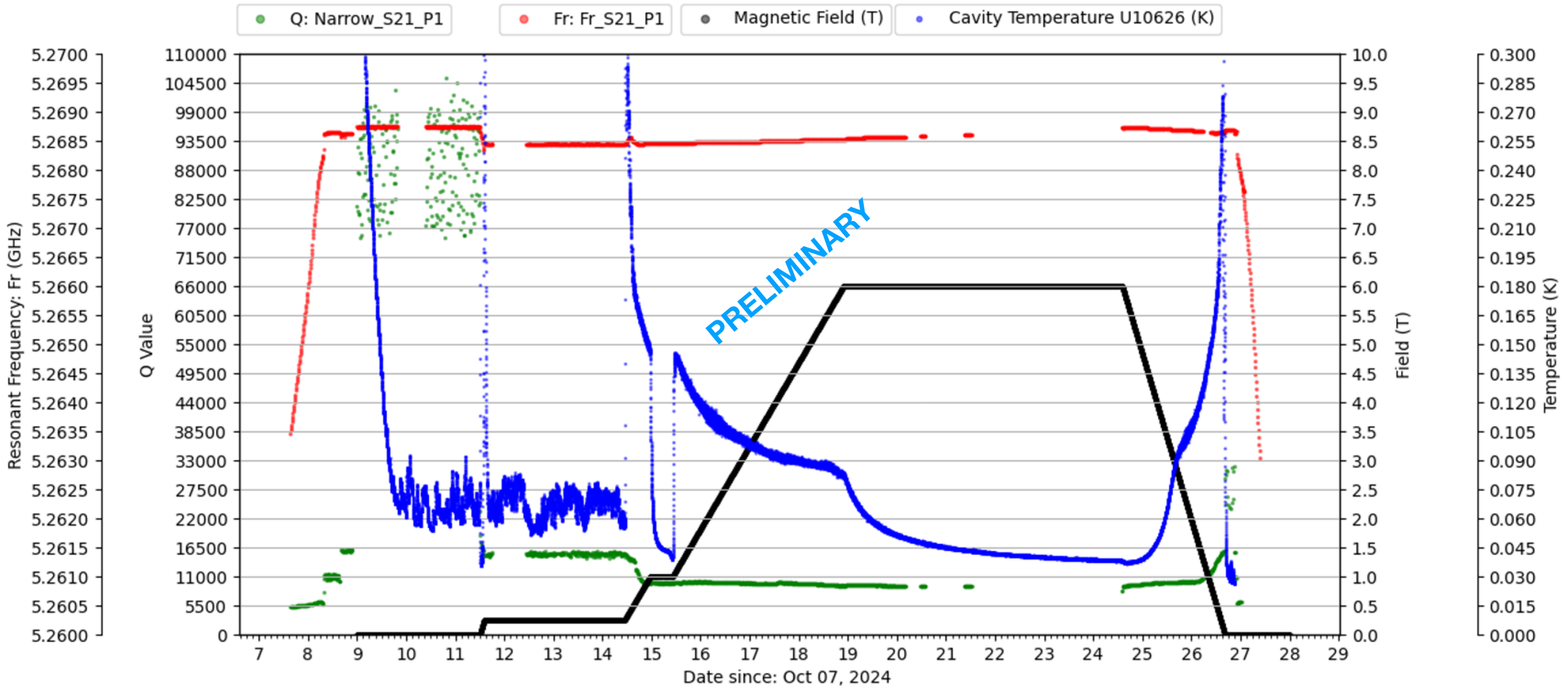
A Alsulami et al 2025 New J. Phys. 27 105002; arXiv: 2504.12257

Magnetic field shield



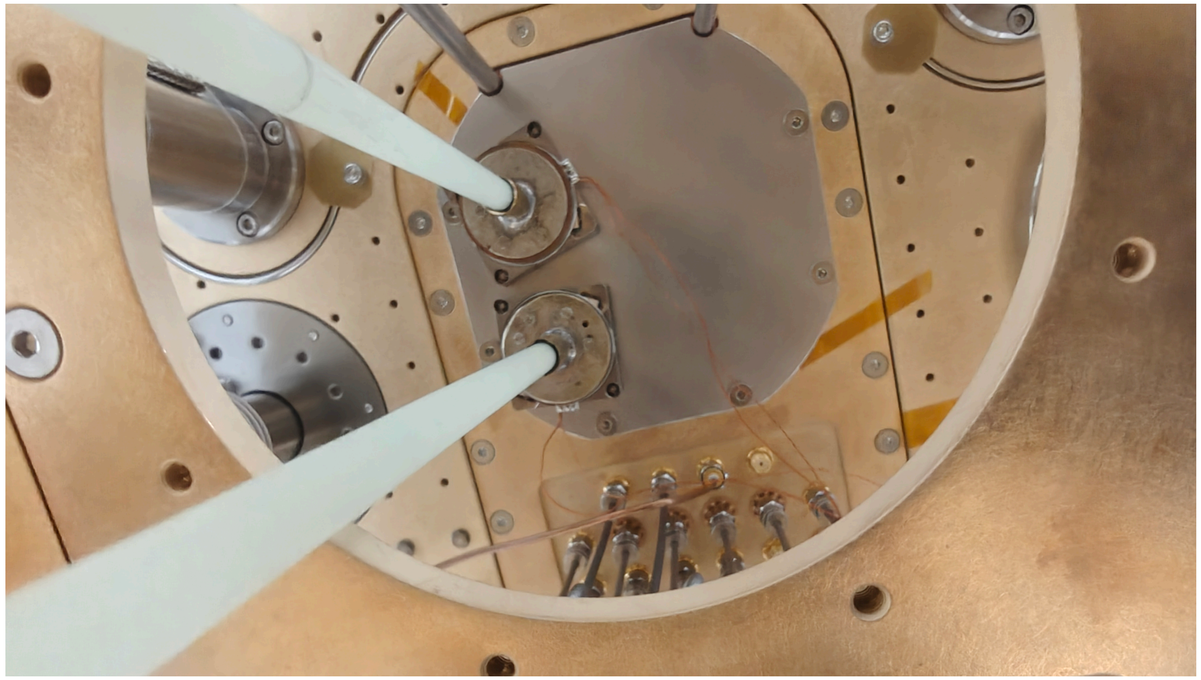


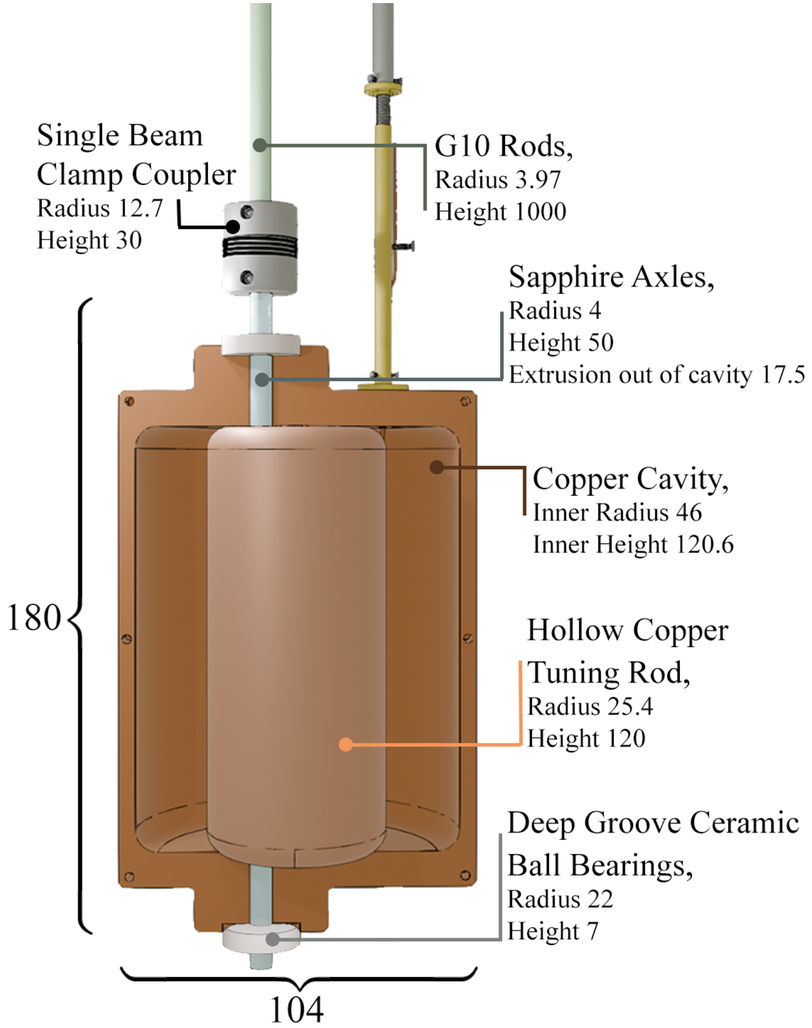
Joint tests with ADMX at QSHS of an aluminium cavity containing a NbSn coated Niobium tuning rod.

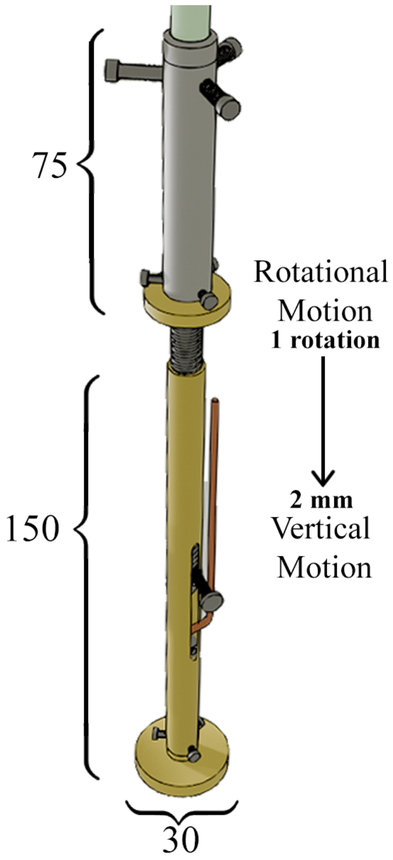


Cavity tuning

- Direct drive of tuning rod rotation from attocube piezo drives at 4K.
- Initially had problems with jamming, found to be caused by residual water ice in the insulation vacuum. Solved by flushing with dry nitrogen gas to half room pressure, then pump out, twice.
- Further jamming problems with antenna mechanism caused by nitrogen ice. Will try a helium backfill next run.

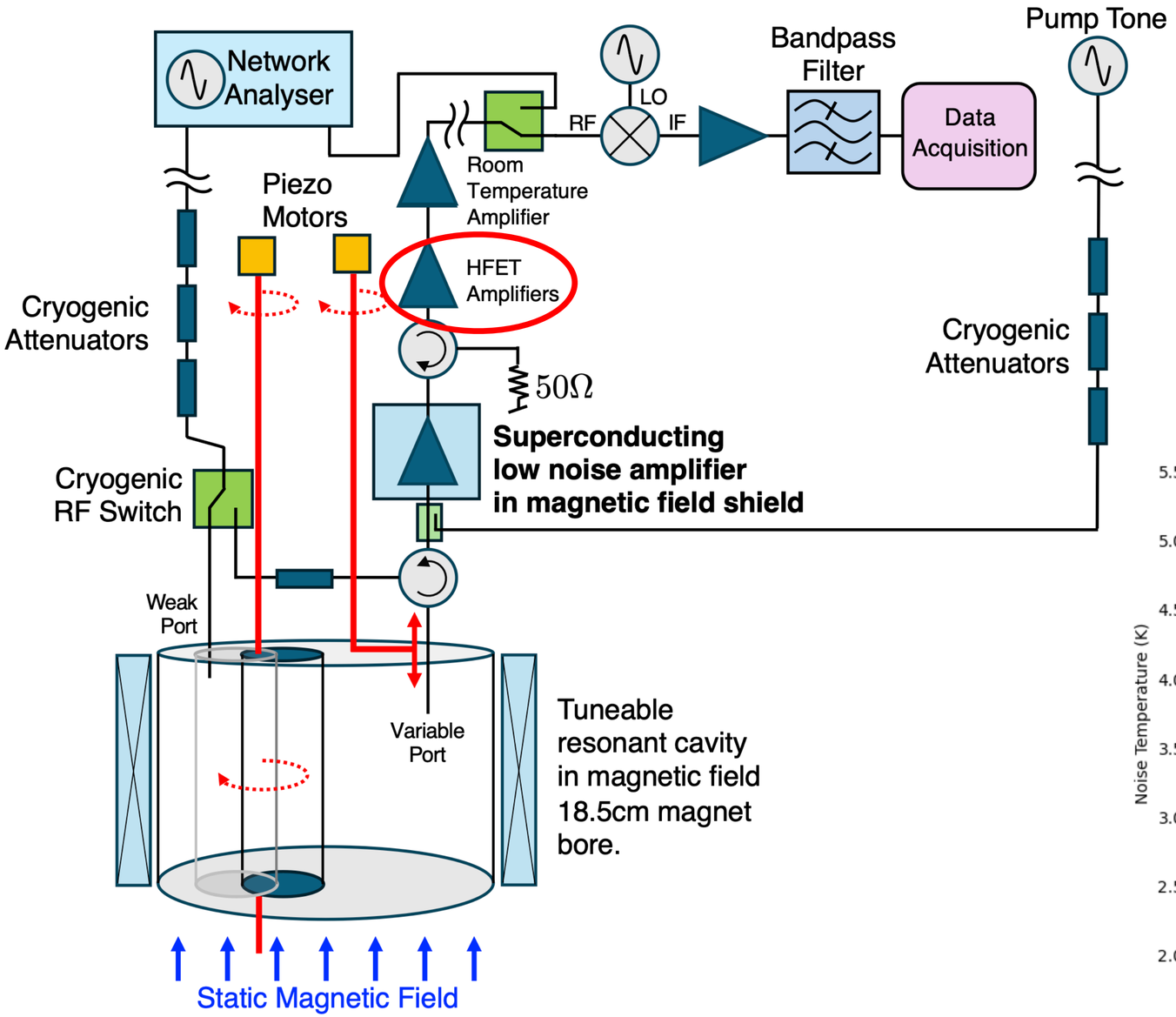




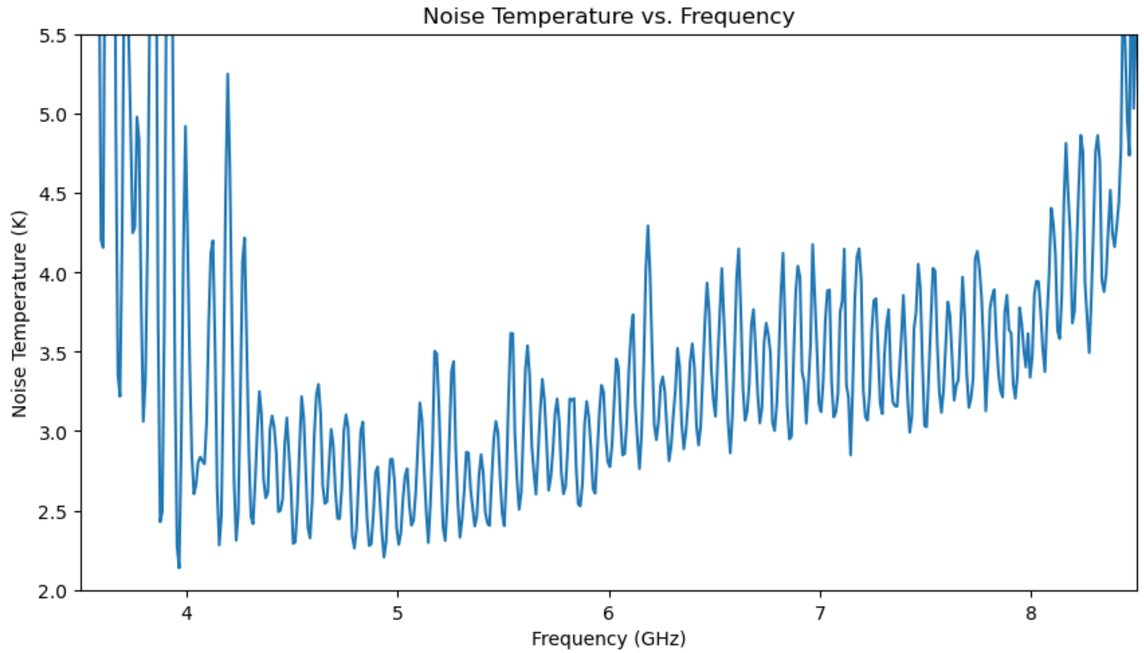


All Measurements in mm

QSHS electronics



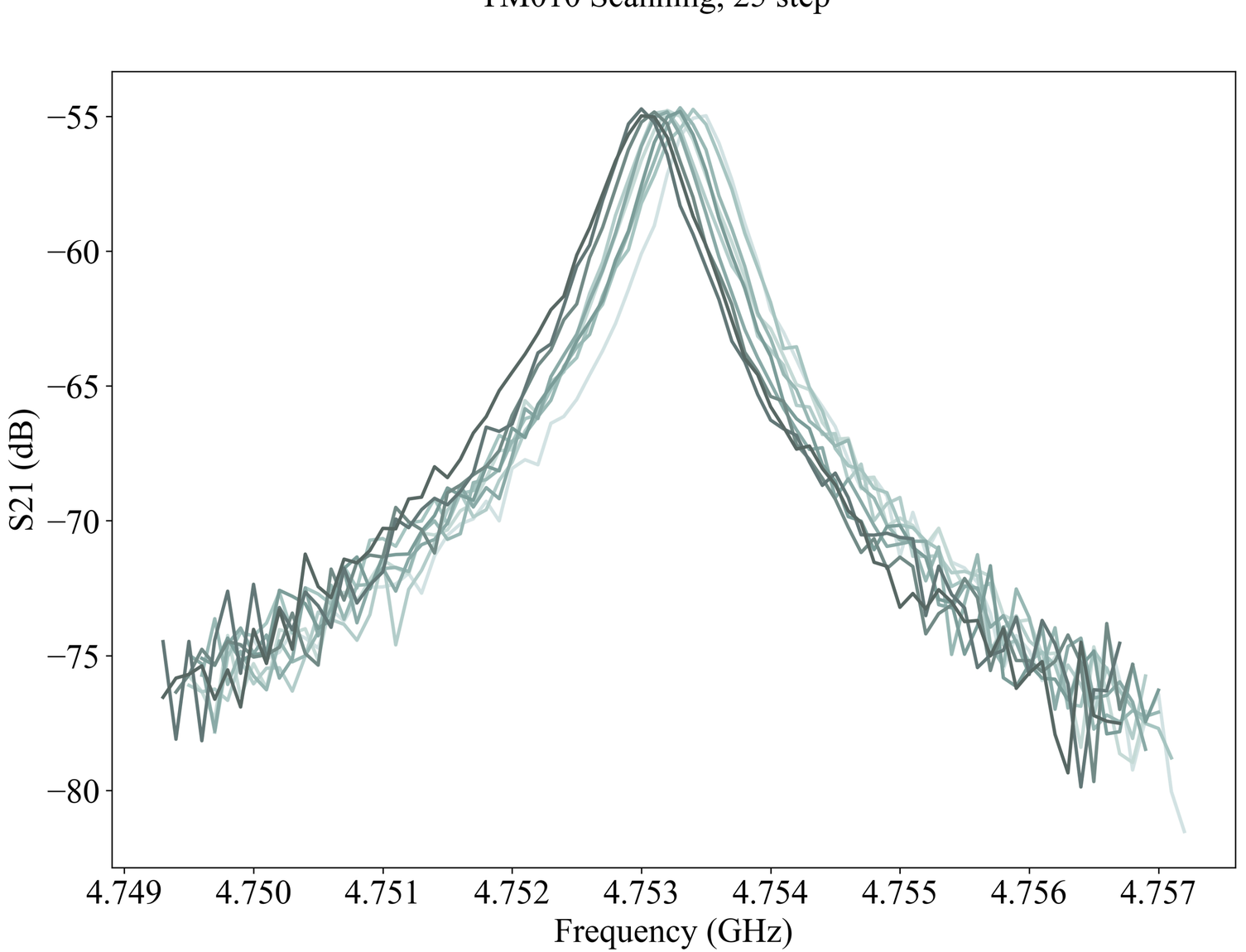
- Two Low Noise Factory LNF-LNC4 8G cryogenic HFET amplifiers in series.
- The lower of these is connected via a long superconducting coax that runs between the 4K plate and below the mixing chamber plate.
- Room temperature amplifier was not installed for this test.



Oscillations will probably go away when we re-install the room temperature HFET amplifier

Tuning the cavity TM_{010} mode frequency

Using the attocube rotary drives to move the tuning rod.



Conclusions

- ADMX continues to exclude QCD axions at the DFSZ phenomenological model level.
- Narrow-bin search results published two days ago.
- Four cavity array system commissioning in the ADMX cryostat to commence in 2026.
- QSHS is a new apparatus in the UK, funded by STFC.
- Initially it is functioning as a test stand for advanced quantum electronics, but has axion sensitivity as well due to the 8T magnet.
- Early QSHS applications have been to test field-tolerant superconductor coated tuning rods, to work out the bugs with direct drive piezo tuning, and to feed into ADMX's four cavity design.
- Last 'jamming' bugs probably caused by nitrogen ice; about to re-cool and test this hypothesis.
- First axion search run will start in late 2025.