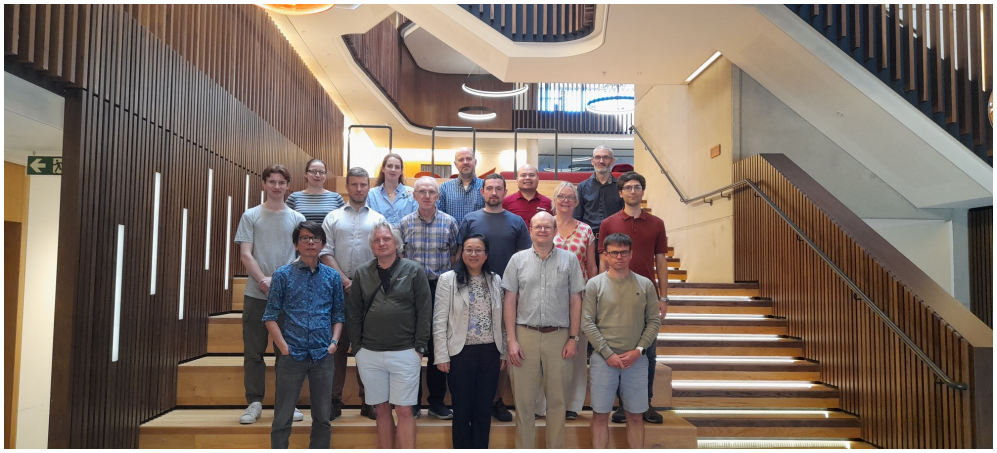
Quantum Sensors for the Hidden Sector



Ed Daw, on behalf of the Quantum Sensors for the Hidden Sector collaboration

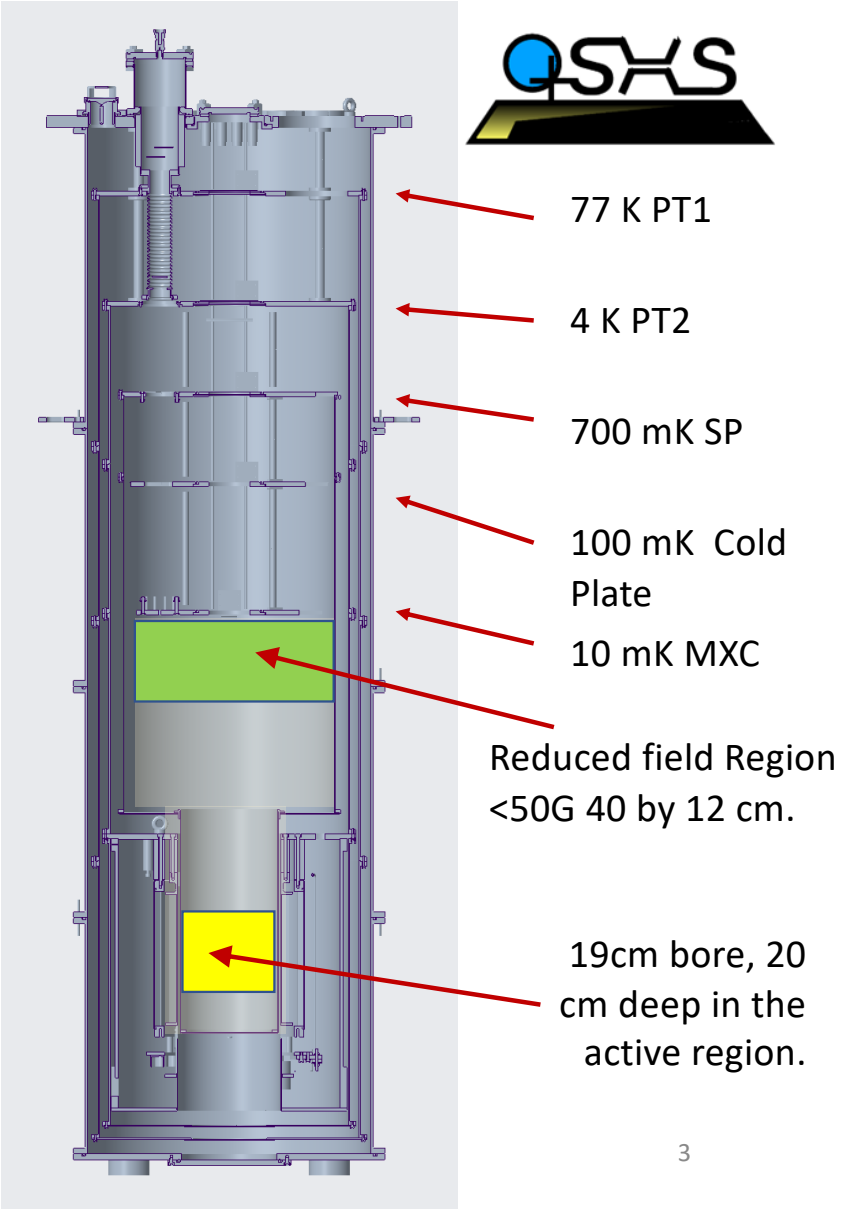
TAUP Conference 2023, Vienna

Aims of QSHS

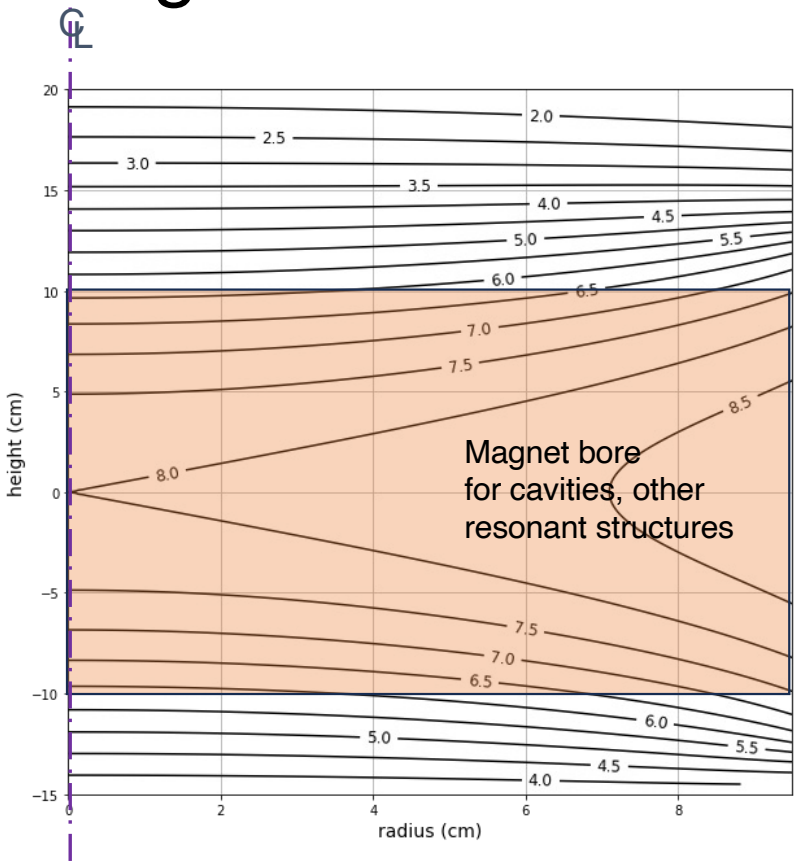
- Develop and test quantum and high-sensitivity electronics for axion and other hidden sector particle searches.
- Drive the temperature at which cavity-based searches operate down to ~10 mK permitting QSHS to work at the single photon detection level.
- Build a flexible UK test with significant sensitivity.
- Use the test facility to develop new ideas for hidden sector dark matter searches.
- Conduct a first search for halo axion dark matter at a photon frequency of around 5 GHz, axion mass 25 micro-eV. These results will be extrapolated to an projected sensitivity for proposed larger facilities.

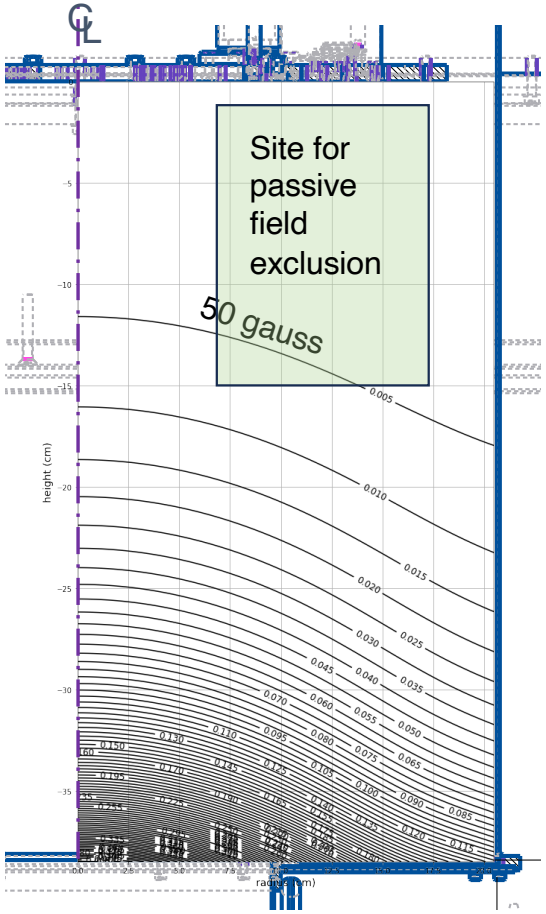
Dilution Fridge & Magnet

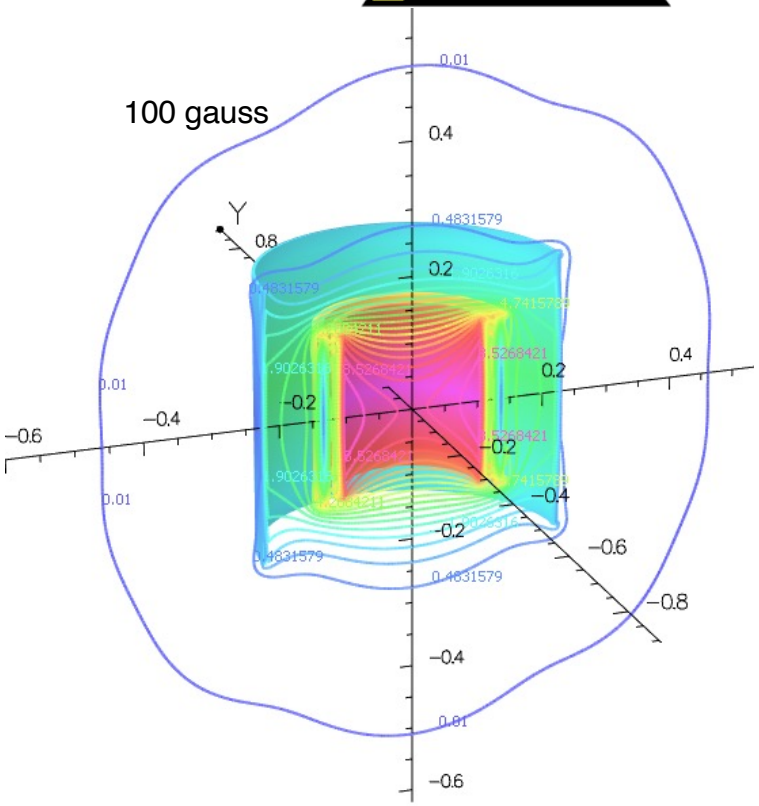
- Oxford Instruments dilution fridge.
- Proteox MX
- <10mK at mixing chamber plate
- 8T nominal field
- 20cm height, 19cm inner bore
- Field cancellation region with passive magnetic field shield
- **Delivery expected in January 2024**



Magnetic field simulations



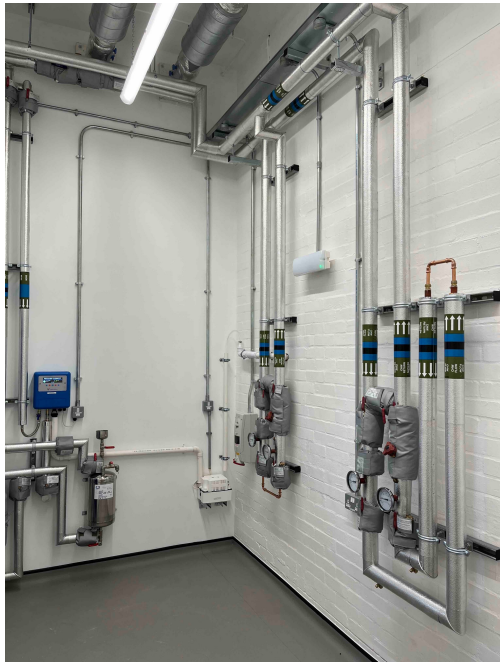


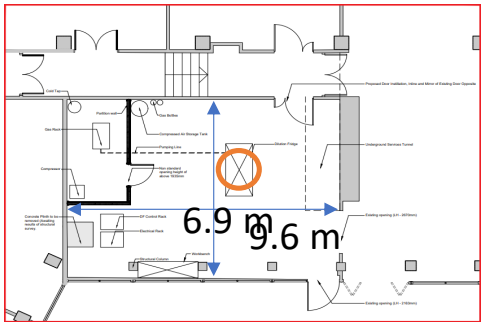


Counterwindings reduce stray field to 100G at 52cm above the centre of the magnet bore. Passive field shield permits field-free region above the magnet and below the mixing chamber plate. 5 gauss line 1.2m from magnet centre.

Niobium titanium outer windings, niobium tin inner windings.

QSHS Lab – Sheffield University UK





Cavity Development

We fabricated two cavities using the ADMX sidecar design.

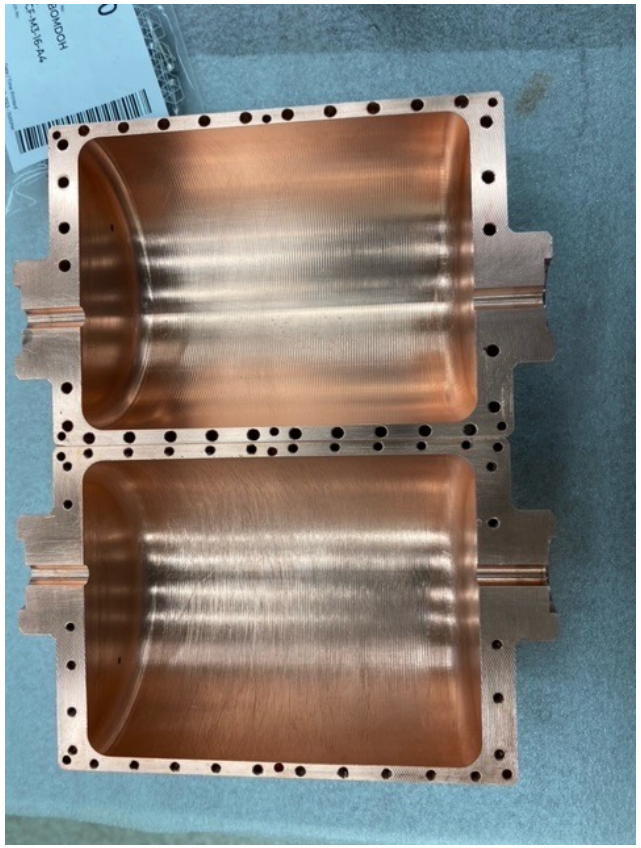
- 2 Copper (1 ADMX & 1 QSHS)
- 1 Aluminium ADMX

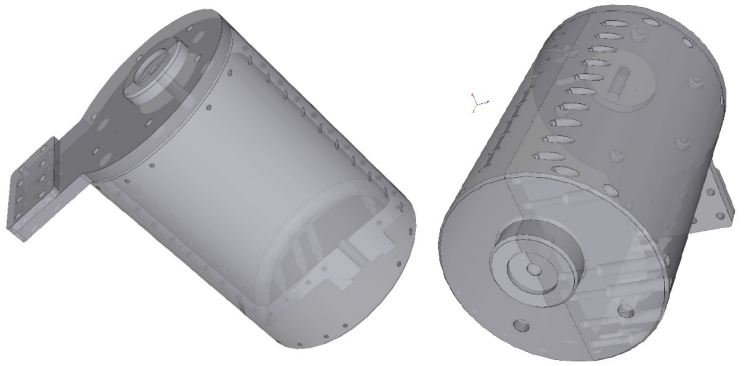
Copper cavity has room temperature Q in air of 25,000 after hand-polishing.

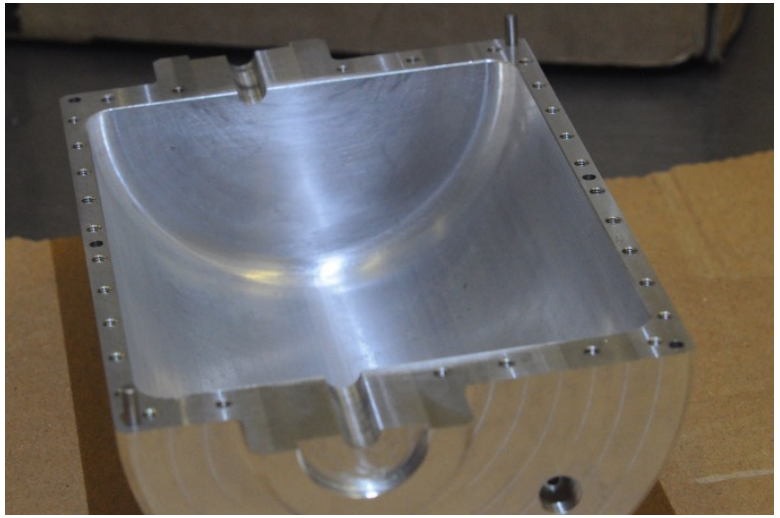
Aluminium cavity had Q unpolished of 17,000 in air. Subsequently cooled to 10mK in dilution refrigerator, Q of 25×10^6 unpolished.

Copper cavity to be installed in ADMX, to replace their existing 'sidecar' cavity, because it has a superior Q.

Other copper cavity to be used in QSHS.



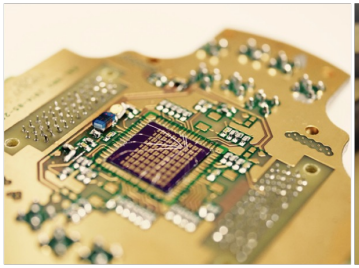
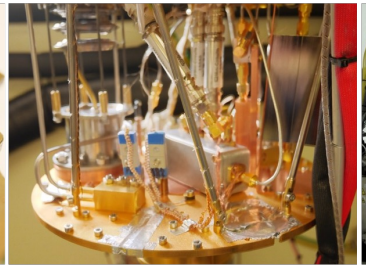




Quantum Electronics for QSHS

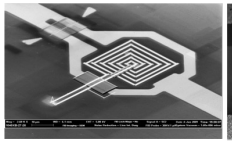
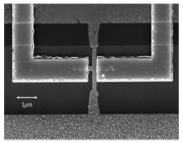
Josephson parametric amplifiers (JPAa) / Travelling wave parametric amplifiers (TWPAs)

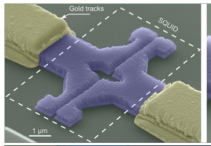
Lancaster University | Royal Holloway University of London | University of Oxford

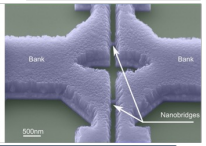




SLUG loaded SQUID amplifiers

UCL | NPL National Physical Laboratory

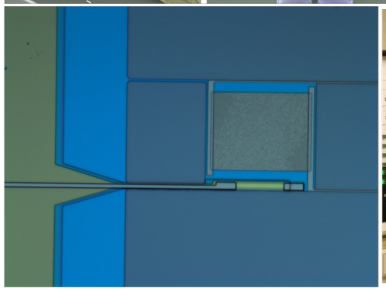
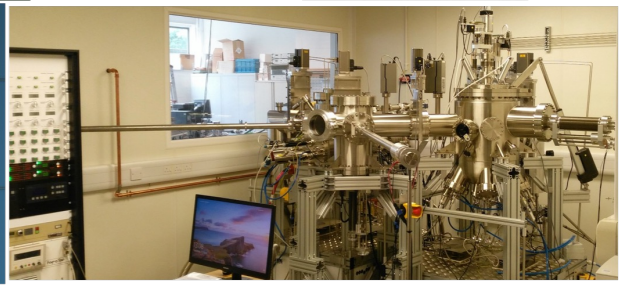







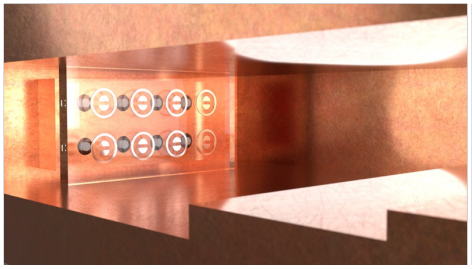
Cryogenic bolometer arrays

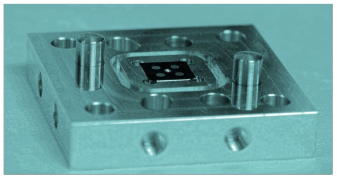
University of Cambridge

Qubit arrays

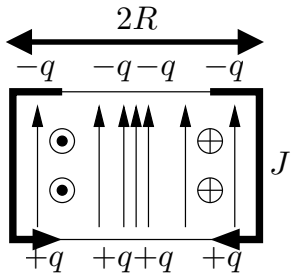
University of Oxford | Royal Holloway University of London



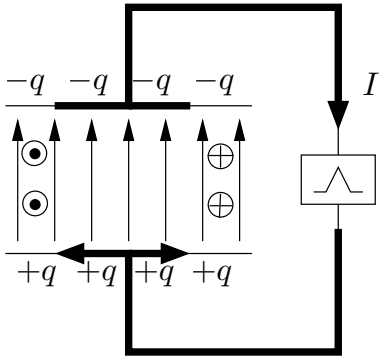


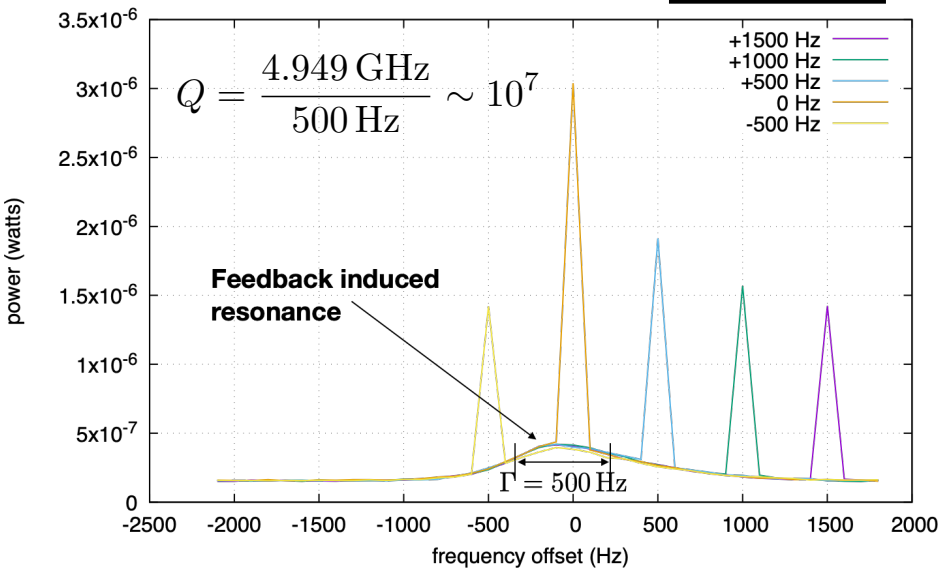
Resonant Feedback

CAVITY

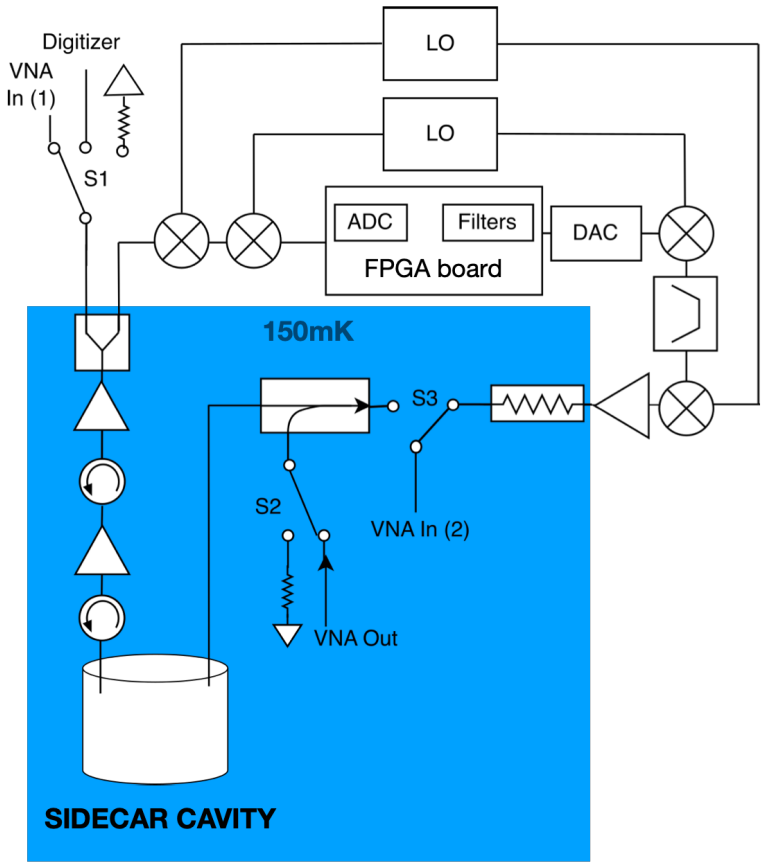


FEEDBACK RESONATOR





ADMX prototype test (Daw, Perry, Bartram)



Nuclear Inst. and Methods in Physics Research, A, Volume 921, p. 50-56. https://arxiv.org/abs/1805.11523

Conclusions

- QSHS is a new resonant axion search collaboration focusing initially on low noise microwave electronics to probe the axion mass range 25-40 micro-eV.
- Manufacture of the Dilution Fridge and manget system is underway. Delivery Jan 2024.
- Site renovation is complete.
- Four resonant cavities, one tunable (4-7GHz), three fixed frequency at 5, 7, 15 GHz to be used for first experiments
- Travelling Wave Parametric Amplifiers (TWPAs), SLUG loaded SQUIDS, Power sensors, Qubit arrays under development in the collaboration.
- Quality factor measurements on first cavities manufactured for the project encouraging.
- Early results will allow us to identify promising low noise readouts, extrapolate any science limits to predict the sensitivity of larger facilities, and try new technology ideas such as resonant feedback.