

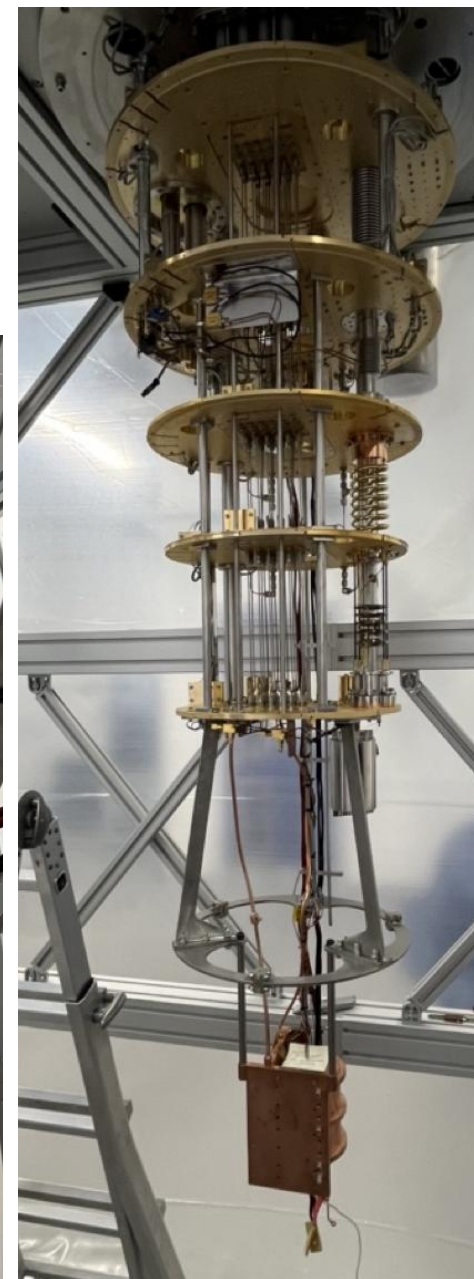
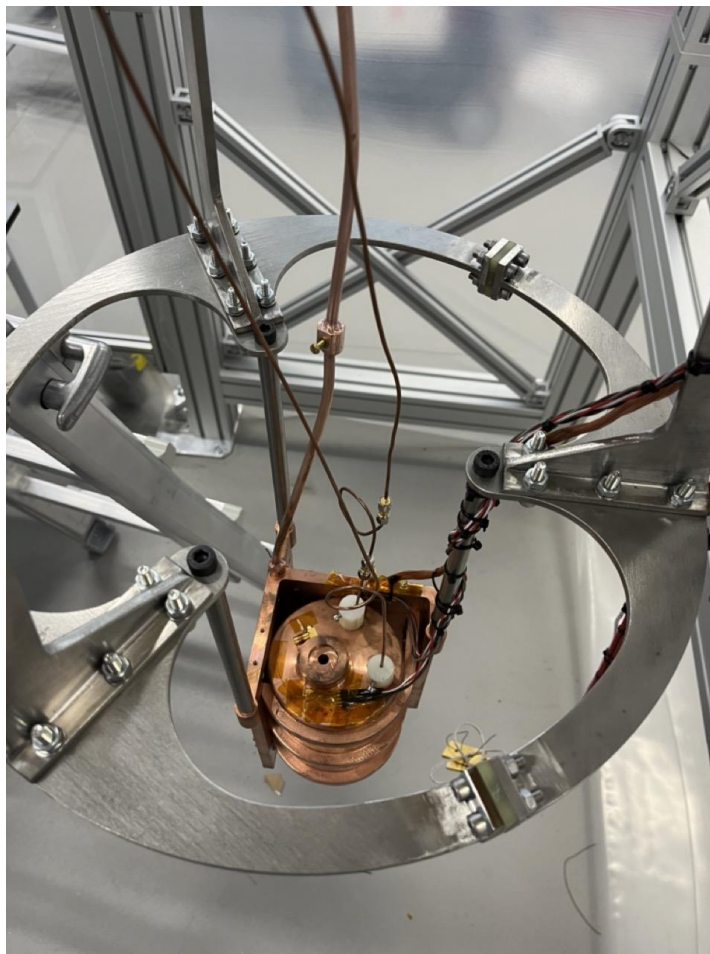
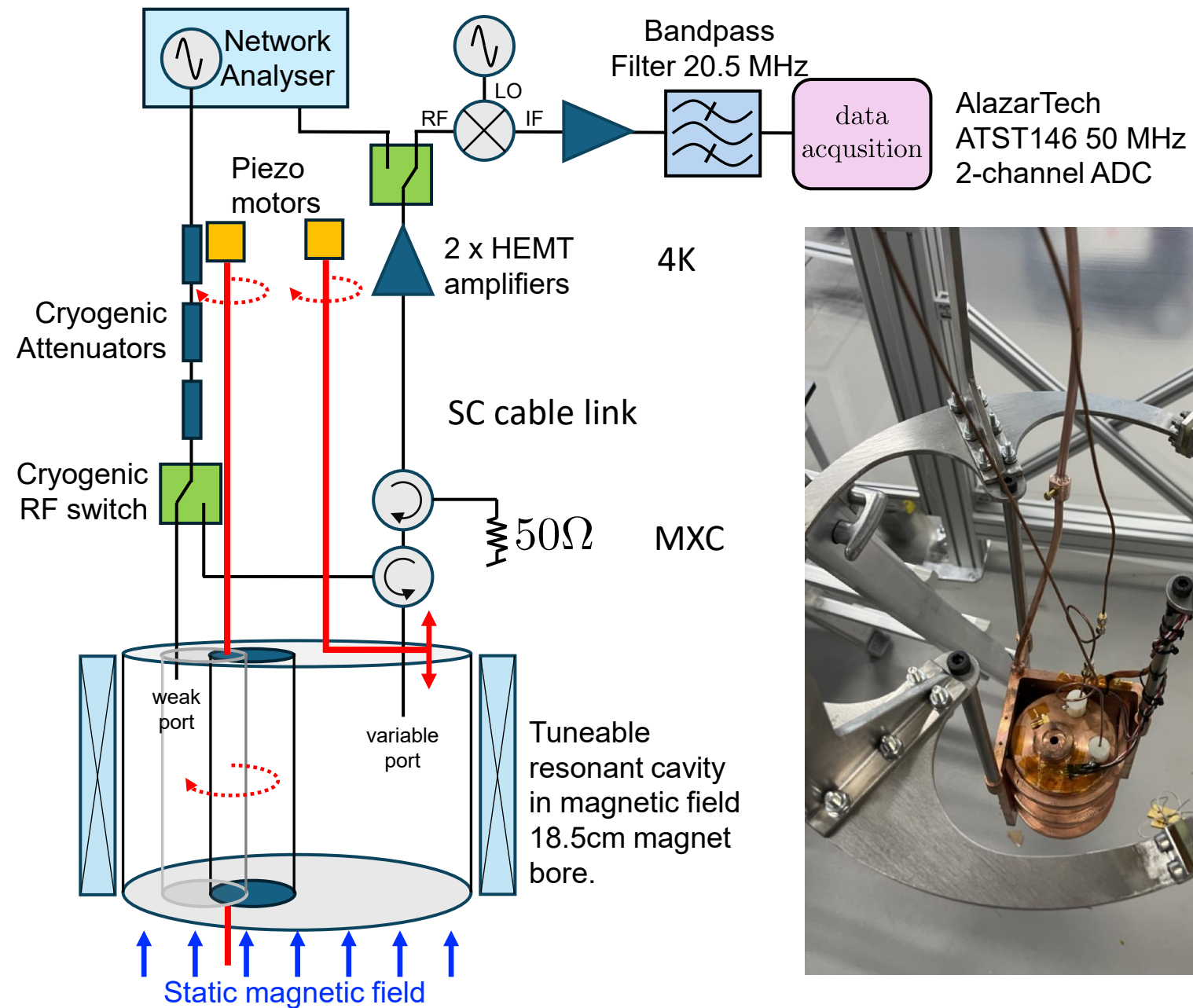
QSHS – HW & DAQ

P J Smith – Axion Workshop

HW Overview

- Schematic
- DF
- Magnet
- Cavity Holder
- Cavity & Tuner
- Motors and Tuning
- Field Shield
- Thermometry
- Electronics in the Fridge

Schematic



The Fridge

Data Acquisition:
Room Temperature

Pulse Tube 2:
 $\approx 4\text{ K}$

Cold Plate:
100 mK

Tuneable 5 GHz Cavity

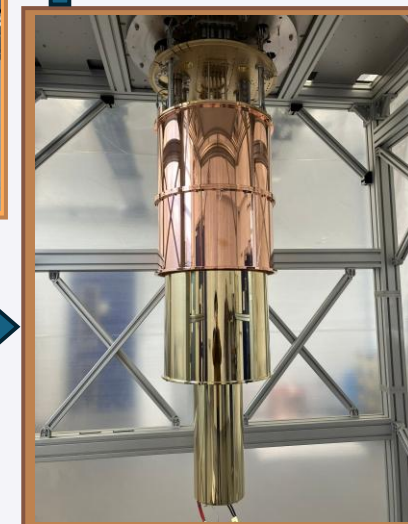
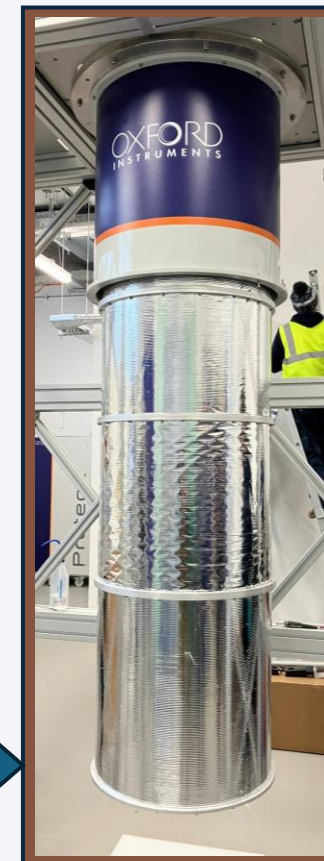
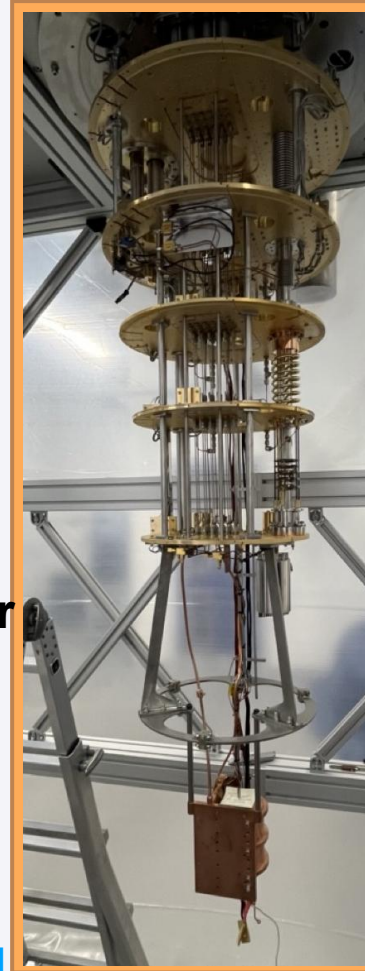
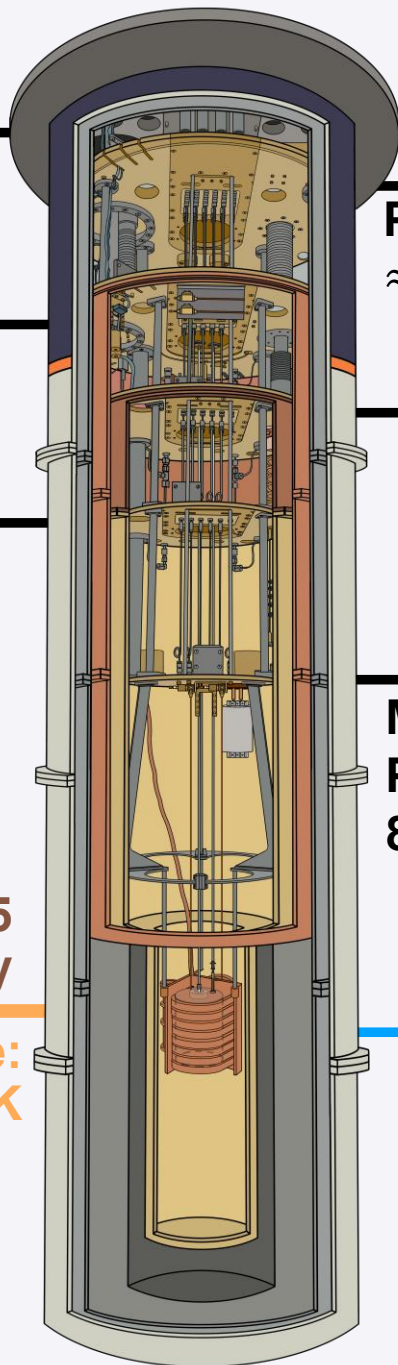
Cavity Temperature:
12 mK

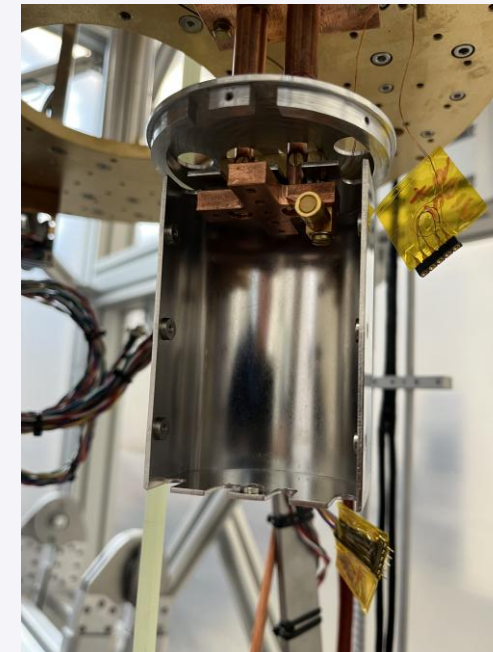
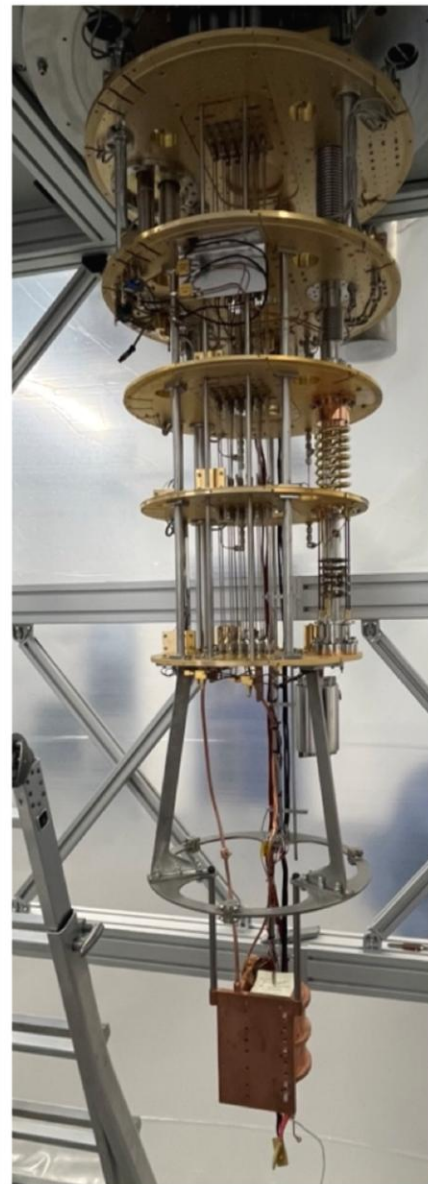
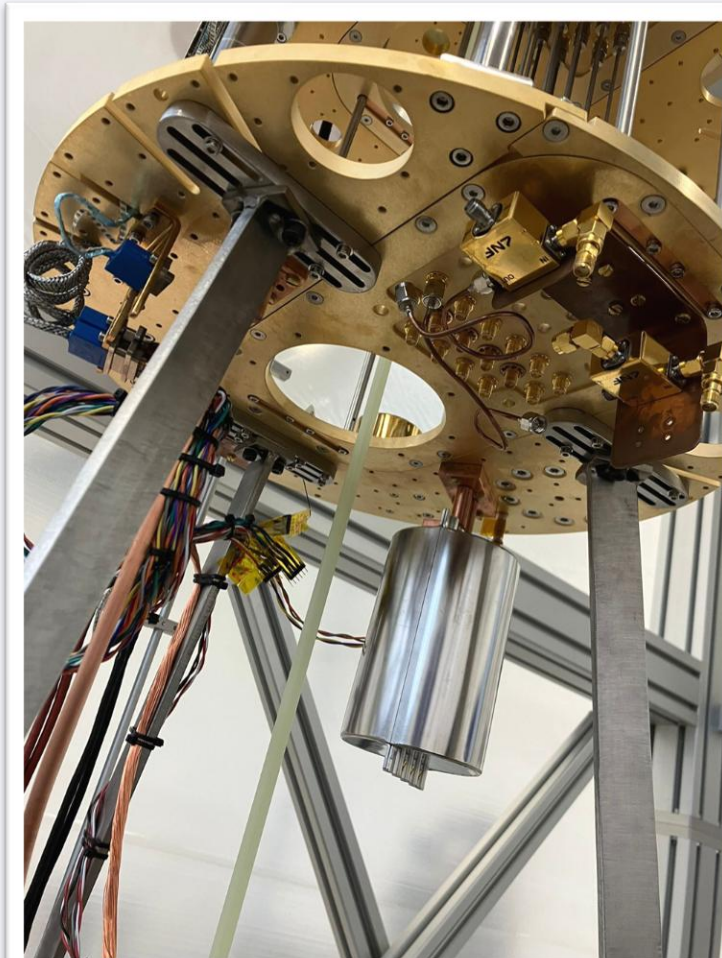
Pulse Tube 1:
 $\approx 70\text{ K}$

Still Plate:
700 mK

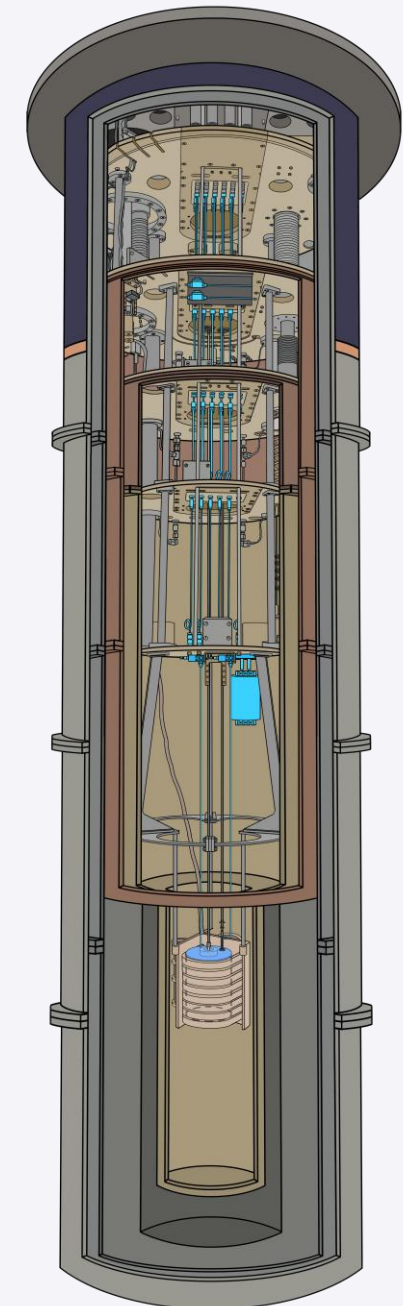
**Mixing Chamber
Plate:**
8.5 mK

**Magnet Internal
Bore:**
18.5 cm



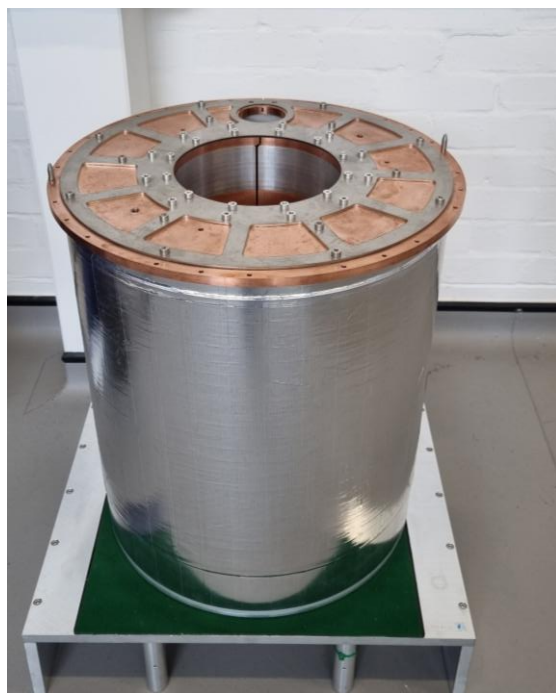


**Field Shield
design,
Ed Laird
(Lancaster)
simulations
by
Paul Smith
(Sheffield)**



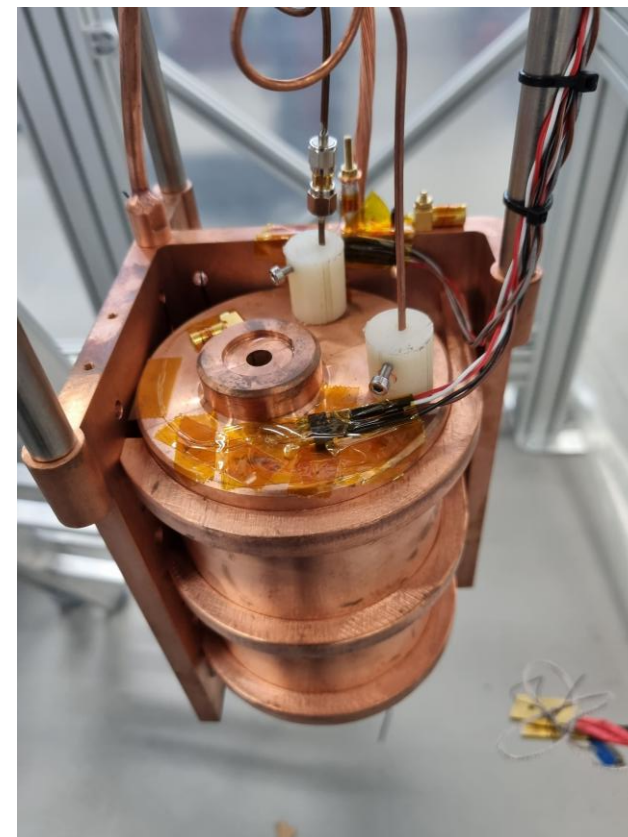
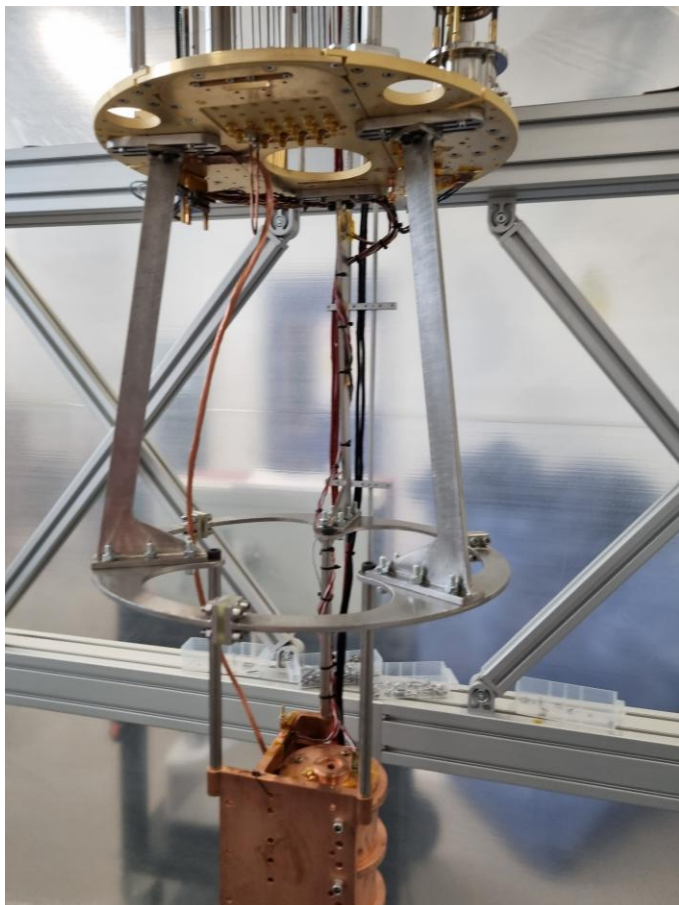
Magnet

- We've had a couple of iterations with the magnet.
- The first magnet reached 6T
- The second magnet can reach 8T but requires very careful handling with the DF
- An upgrade to the DF cooling is required to use the magnet > 6T

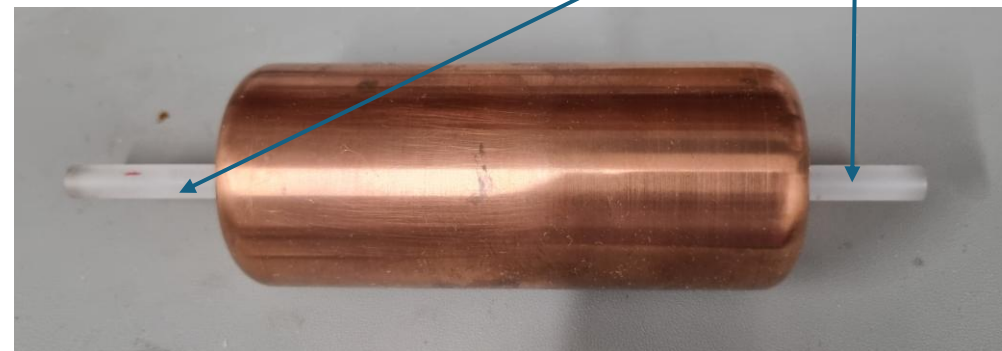
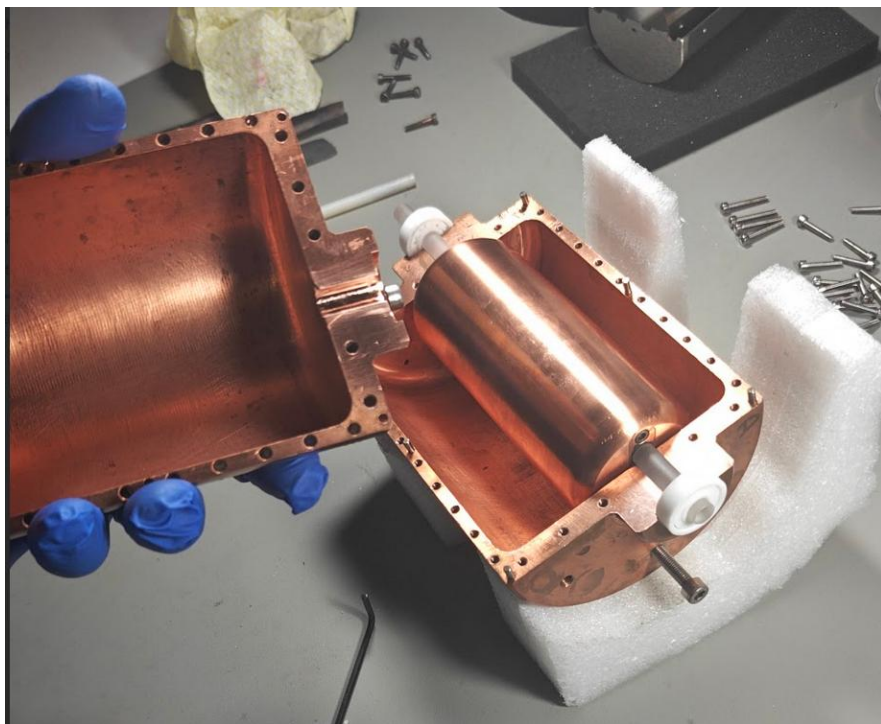
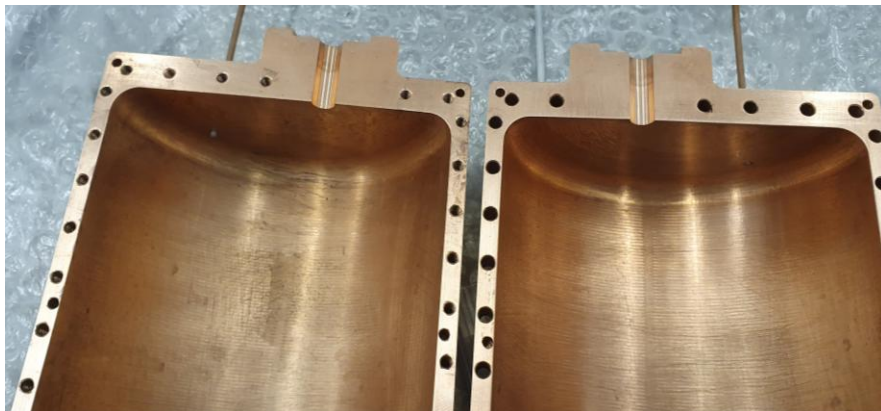


8T SC magnet 2024

Cavity Holder



Cavity & Tuner



Sapphire rods

Al Cavity

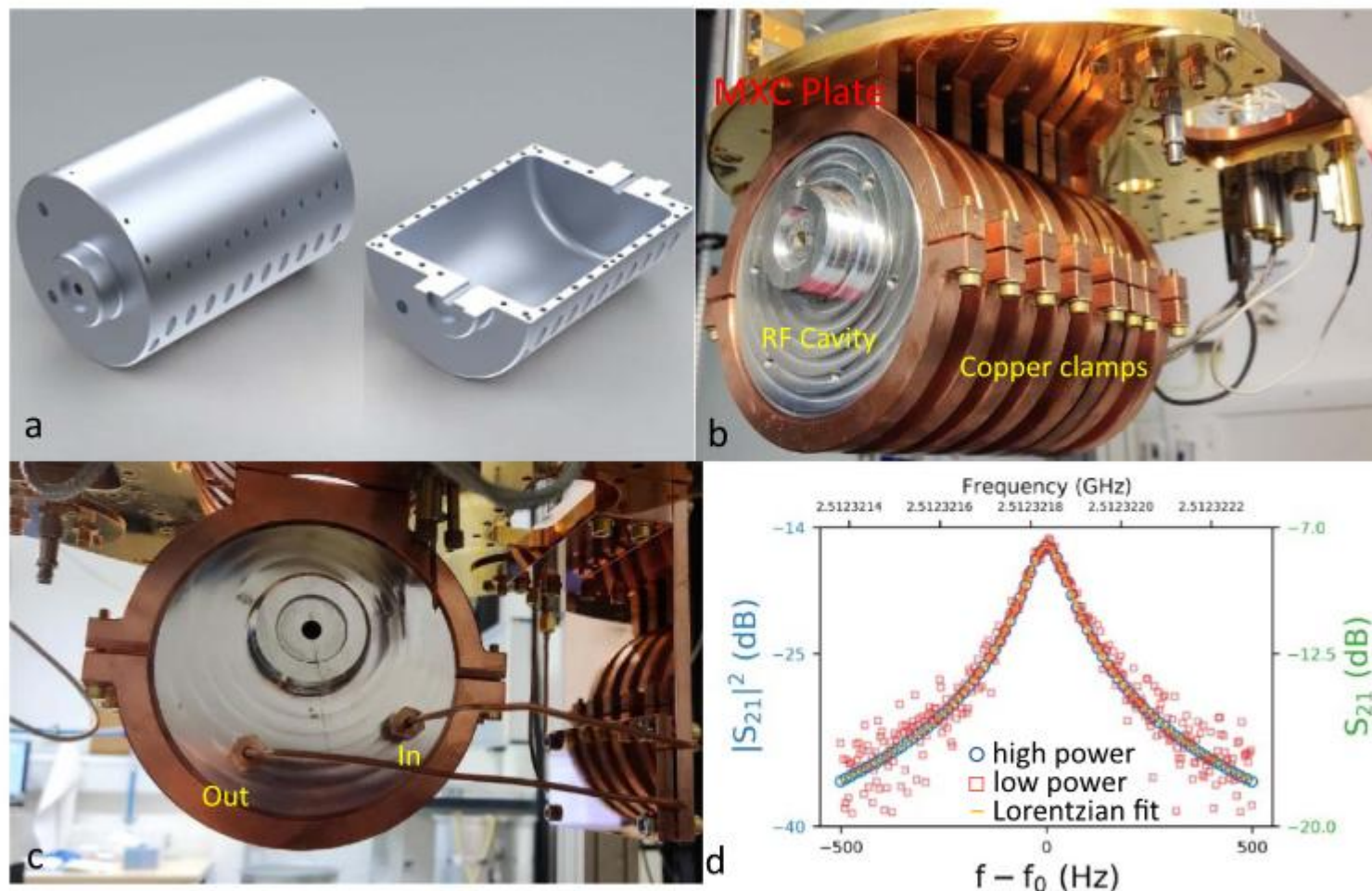
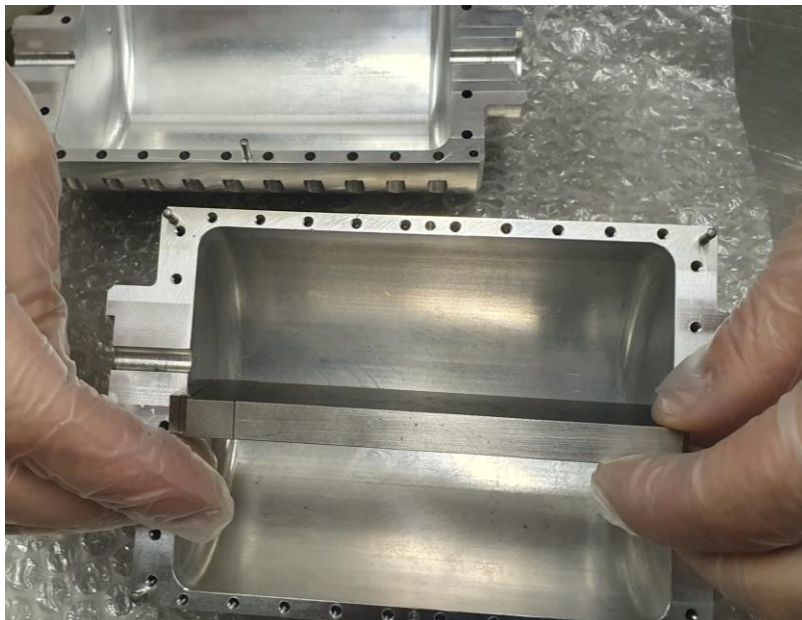
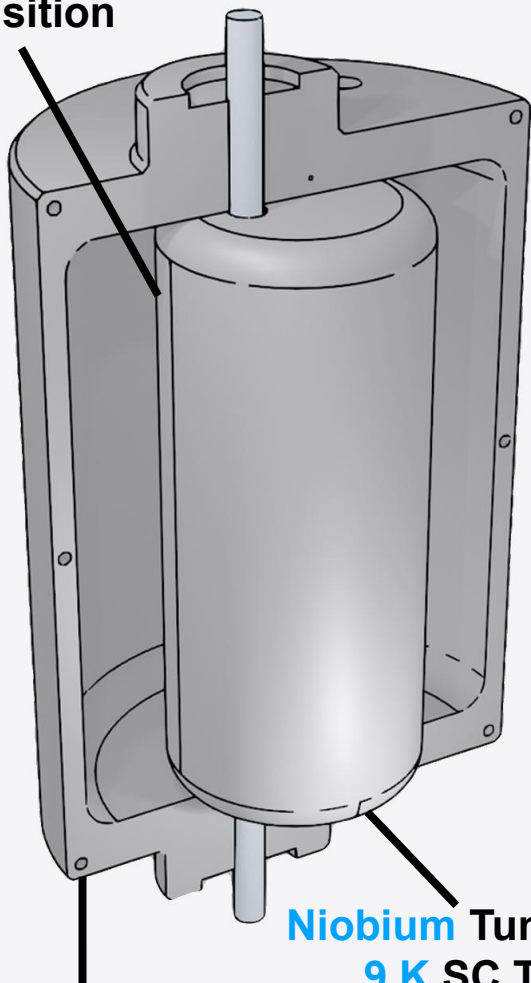


Figure 1. (a) Renders of the measured cavity. (b) Aluminium cylindrical cavity clamped to the mixing chamber plate using copper brackets tightened with brass screws. (c) Copper feedthroughs are secured to the cavity using collet screws. (d) Transmission of the TM_{010} mode of the cavity with a high (blue circles) and low power (red squares) input and corresponding Lorentzian fit (orange line).

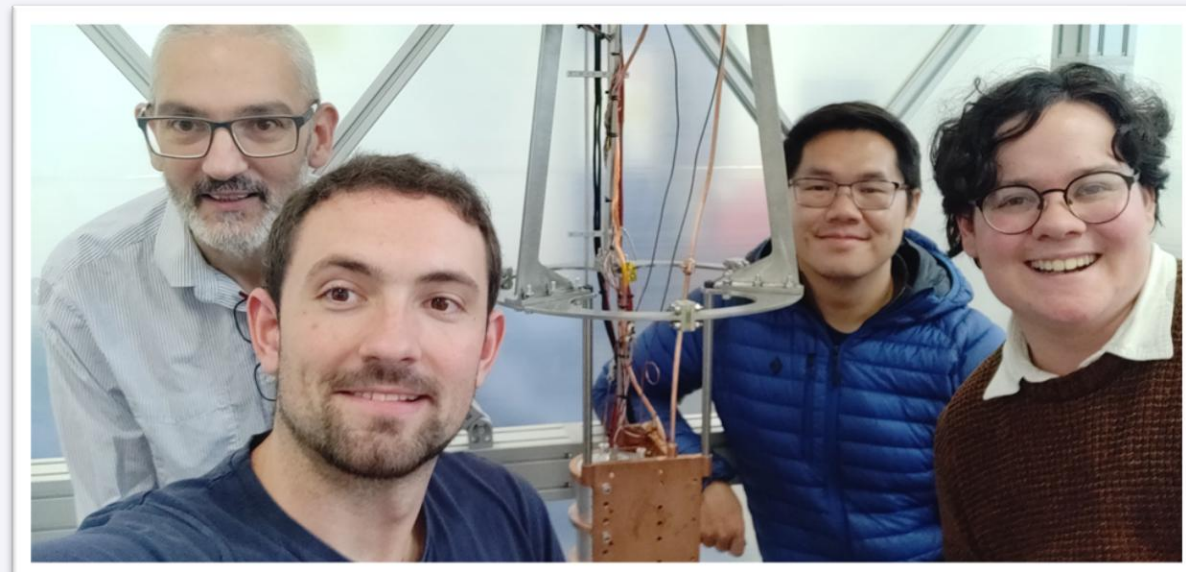
<https://doi.org/10.1088/1367-2630/ae1251>

Niobium Tin Tuning Rod Coating:
11 K Superconducting
Transition

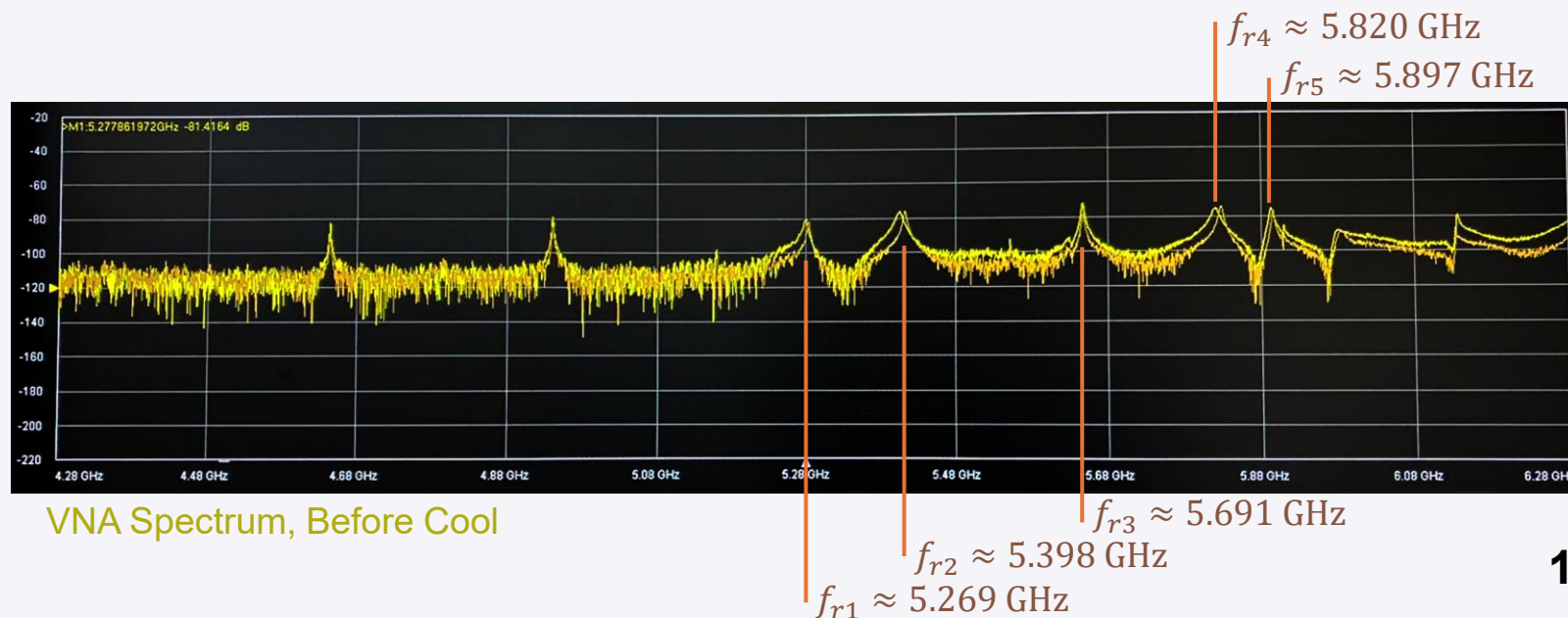


Niobium Tuning Rod:
9 K SC Transition

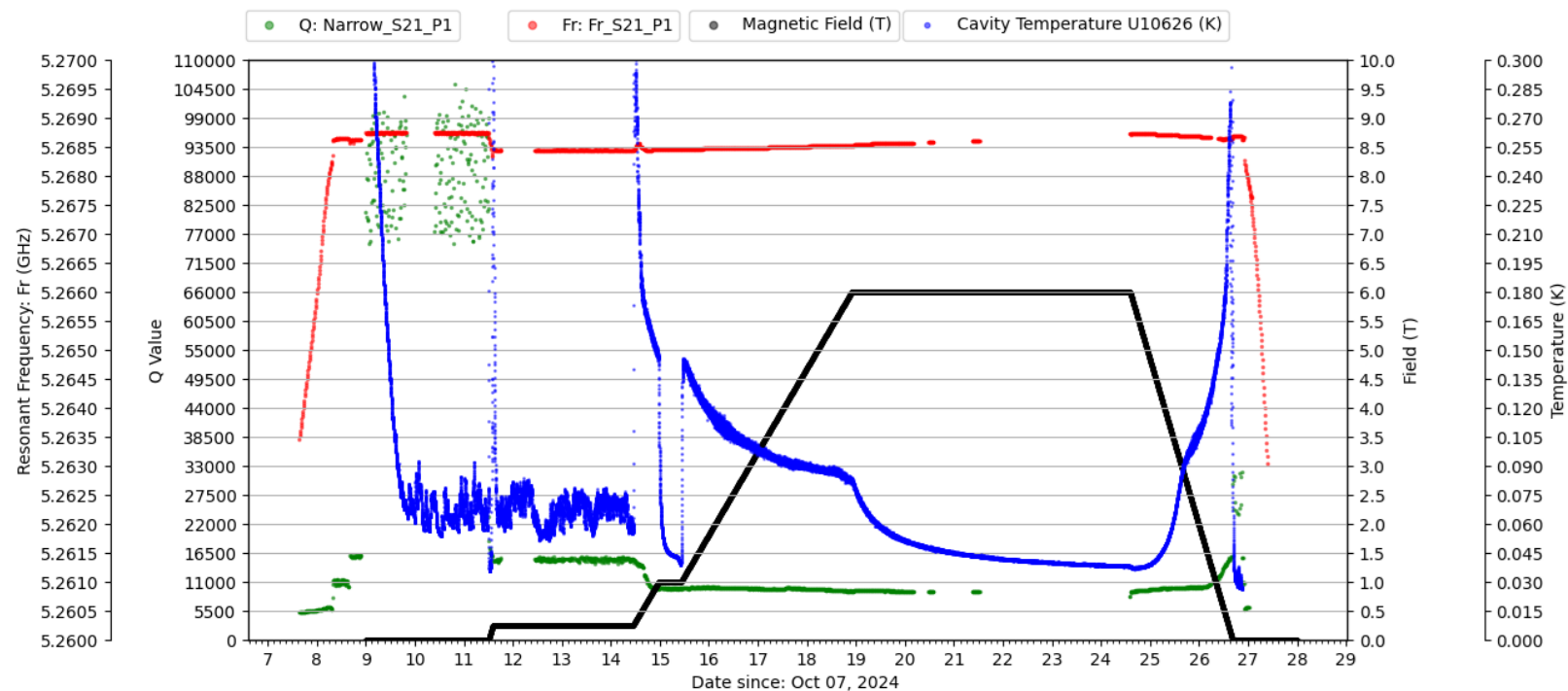
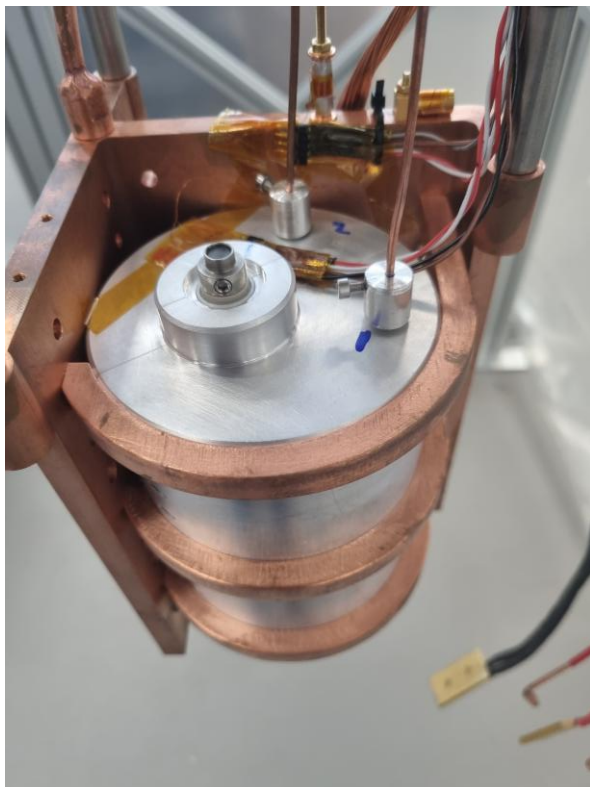
Aluminium Cavity:
1 K SC Transition



Nick Du (Post Doc, LLNL ADMX), Paul Smith (Post Doc, Sheffield), Mitch Perry and Claude Mostyn (PhD Students, Sheffield)



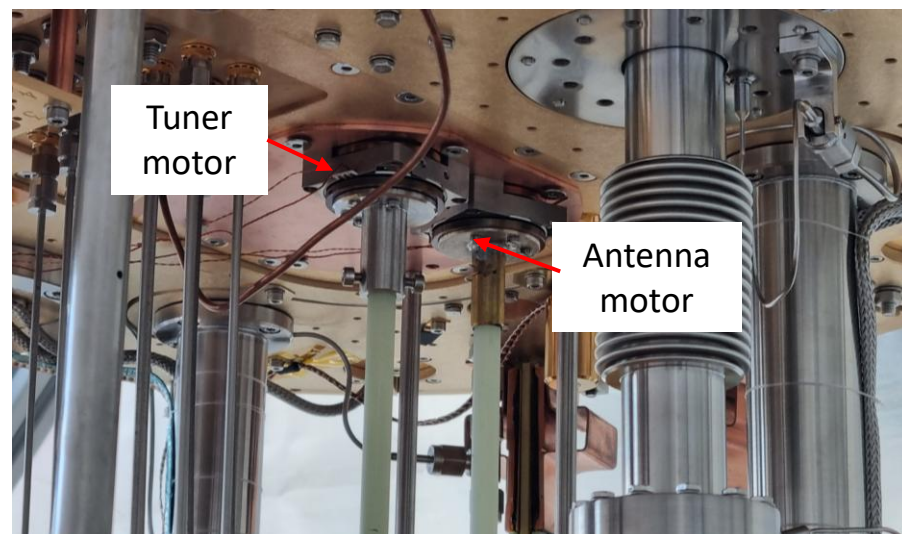
Cavity & Tuner



Tuner material tests with ADMX in 2024

Motor Drives

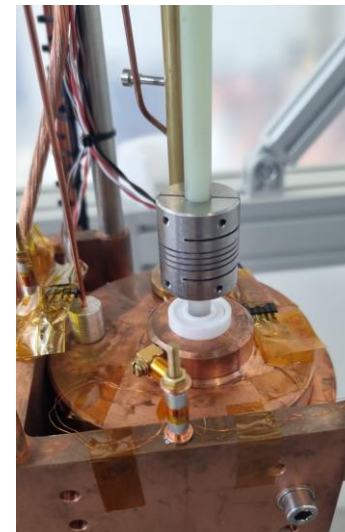
We have 2 x Attocube ANR240 rotator piezo motors installed in the fridge, alongside an AMC300 controller. One motor directly drives the tuning rod, and the other drives the critically coupled antenna.



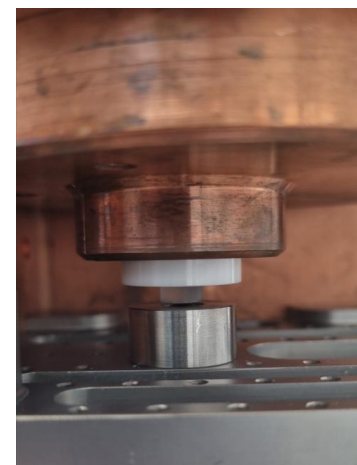
Tuner and antenna motors on the 4K plate. The motors are housed in a recess on a copper plate to ensure repeatable alignment.

Both the tuner and antenna drives work well at Room Temperature under vacuum using the ANR240s.

Tuner

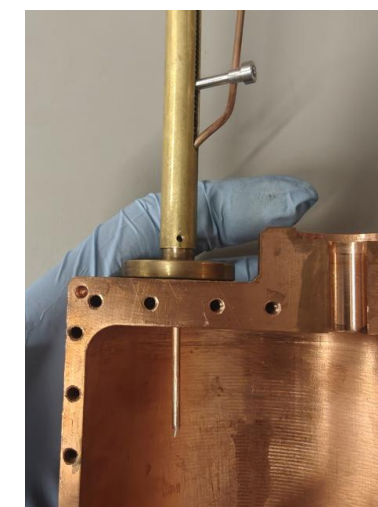


Tuner – this connects to the motor using a G10 rod. A slip joint is included to permit a thermal break and differential contraction.



Critically Coupled Antenna

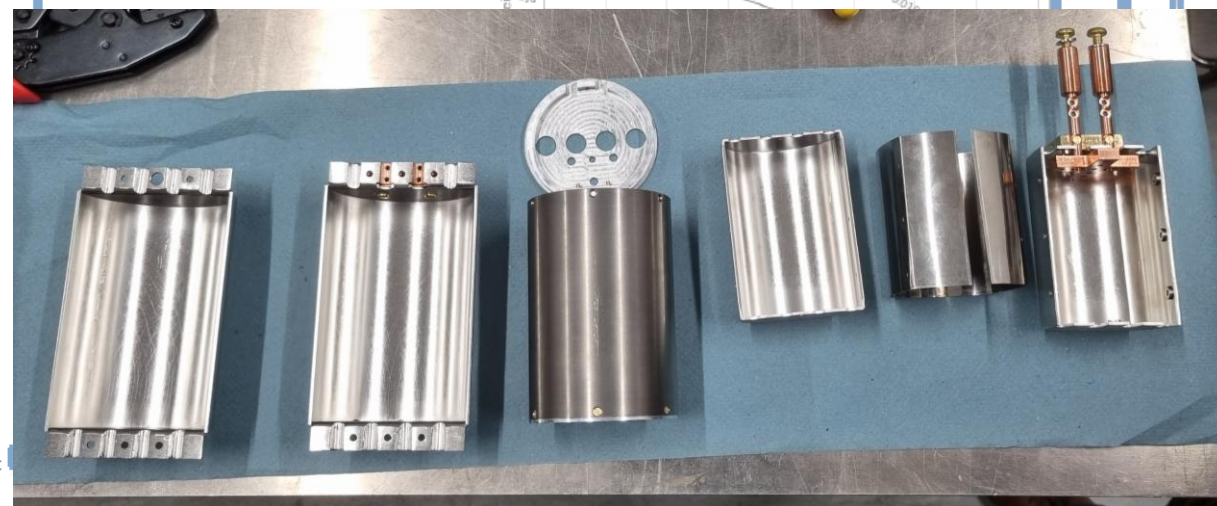
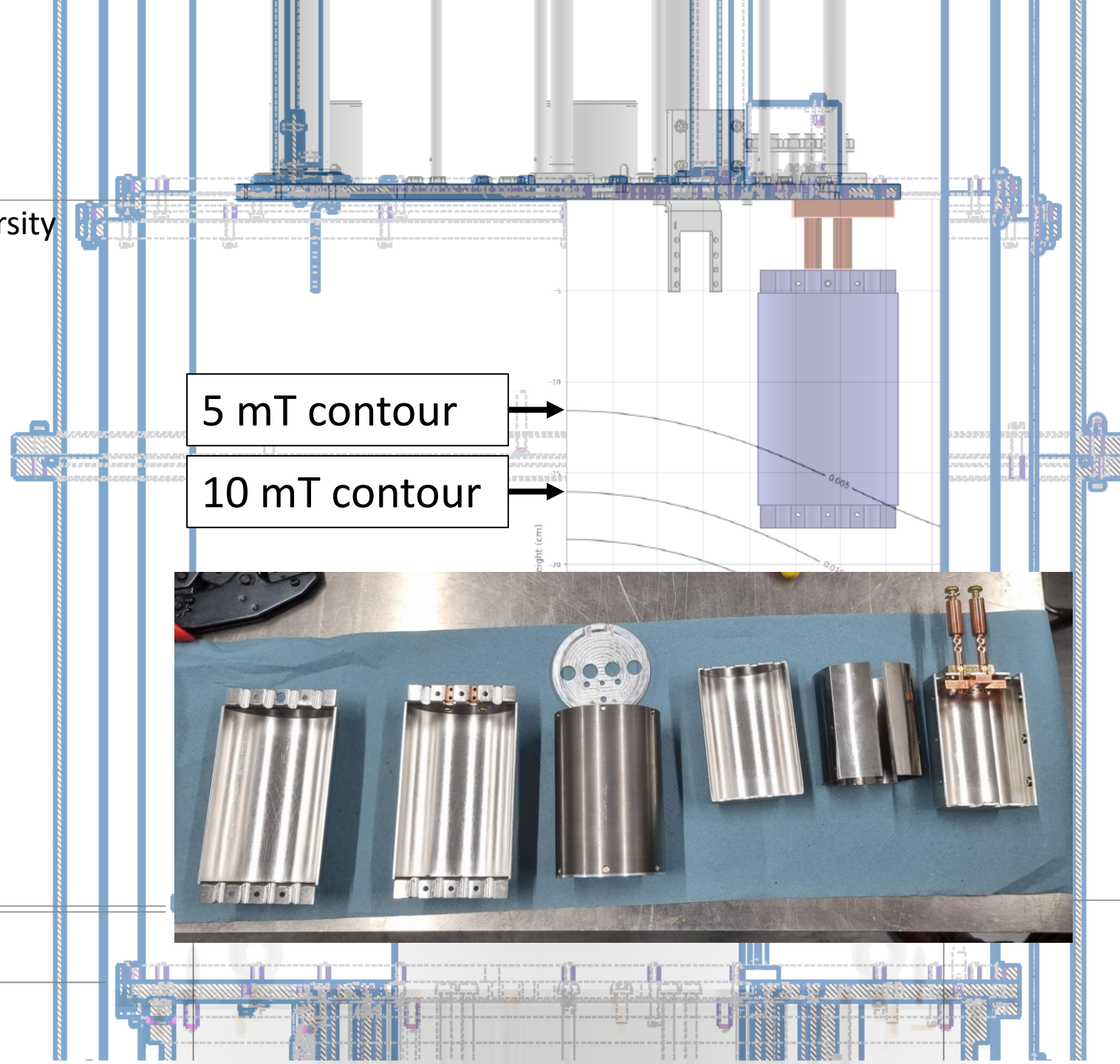
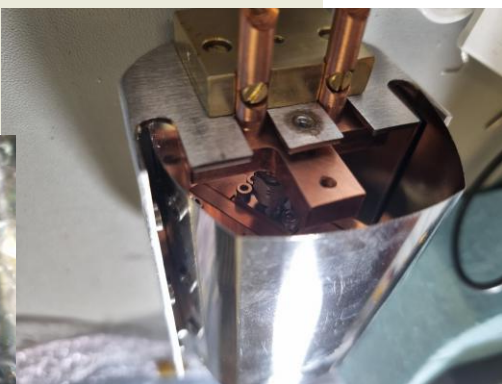
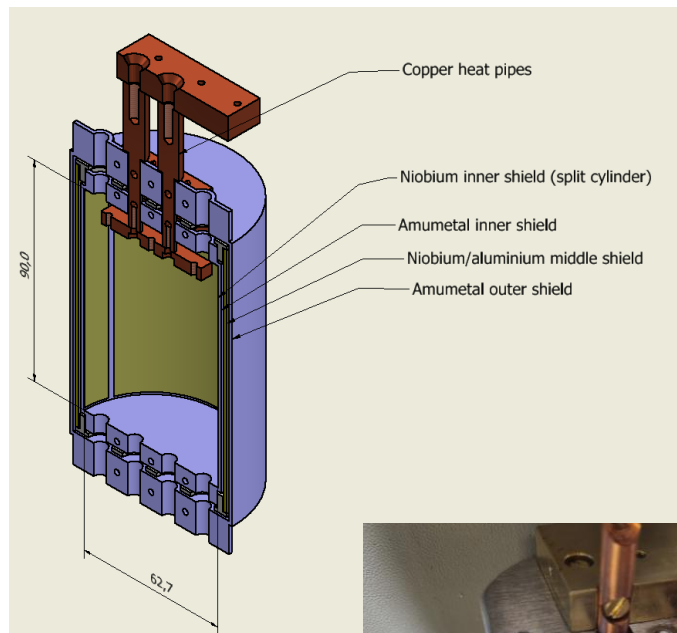
The antenna G10 rod attaches at the top, and the nut's rotation with the fixed thread drives the antenna in/out.





Field Shield

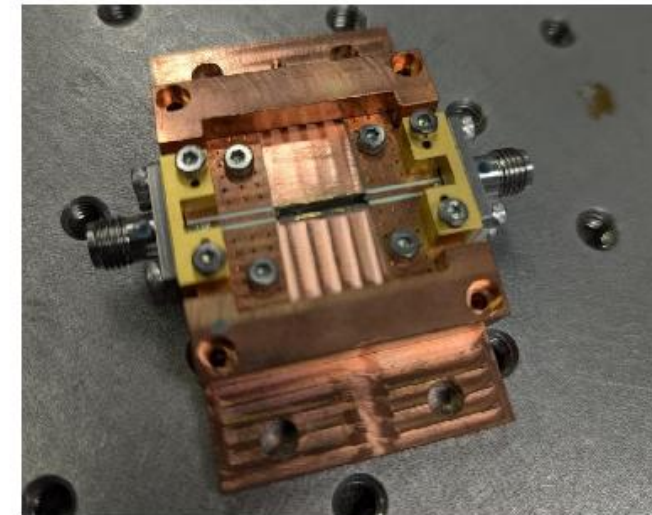
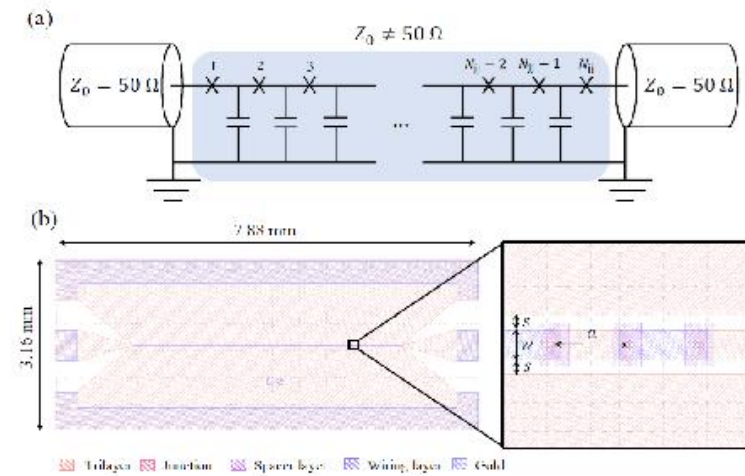
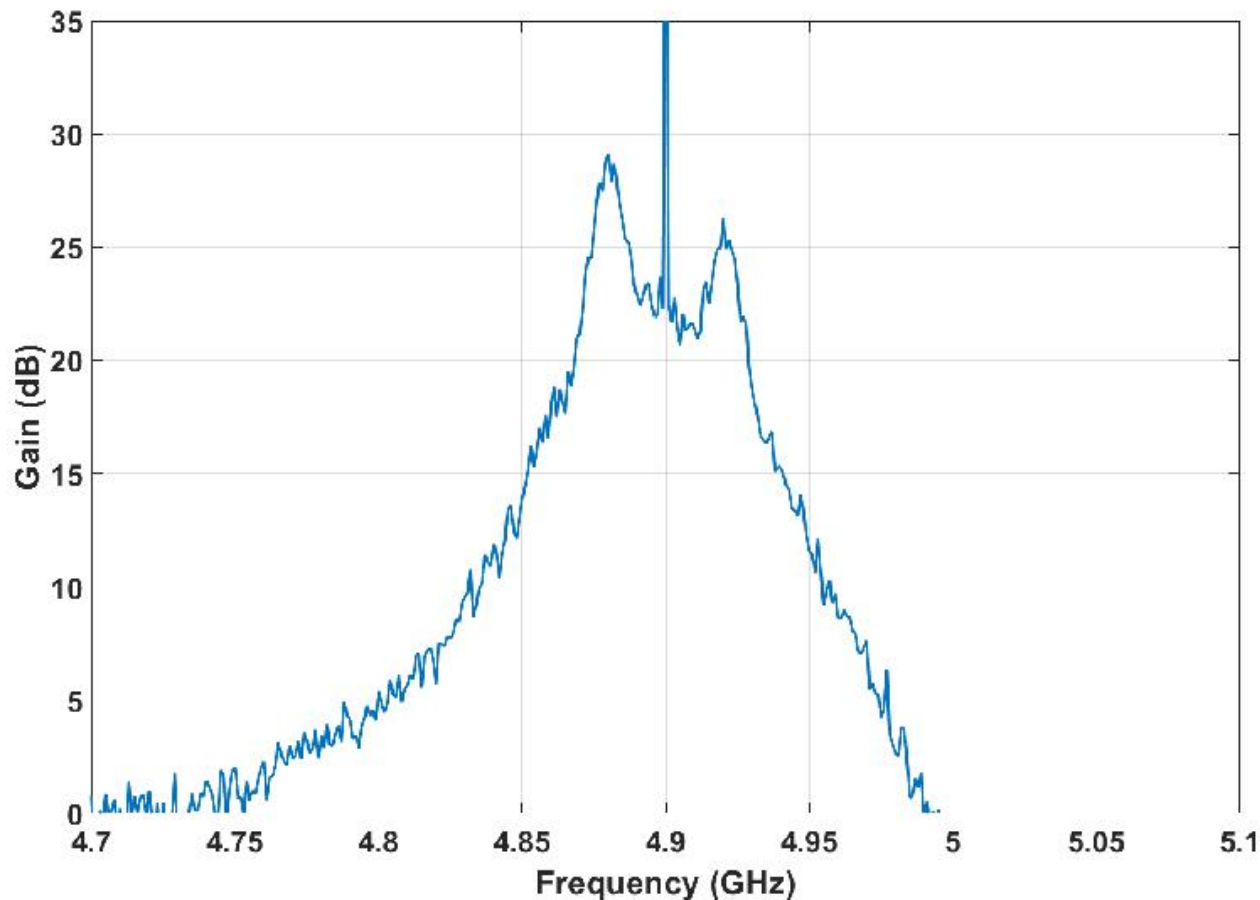
Designed in collaboration with Lancaster University



Standing-Wave Parametric Amplifier (SWPA)

Boon Kok Tan, Senior Research Fellow and Ph.D. student (Oxford)

Narrow > 20 dB gain of ~60 MHz



Thermometry

The DF provides ample thermometry for the fridge itself, but we wanted the option to measure the temperature of various parts of the experimental apparatus.

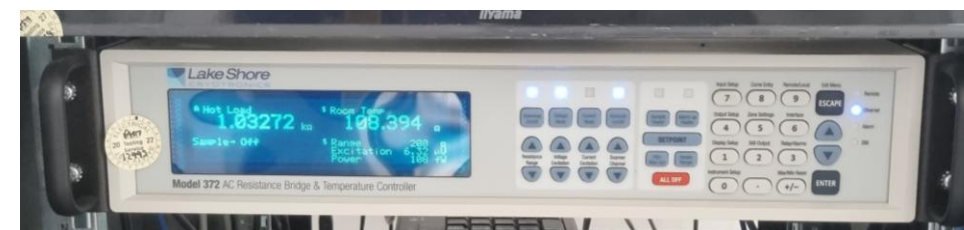


2-wire Rox Sensor
M3 mounting
Range: 40 K to < 10 mK



4-wire Cernox
M3 mounting
Range: RT - 4 K

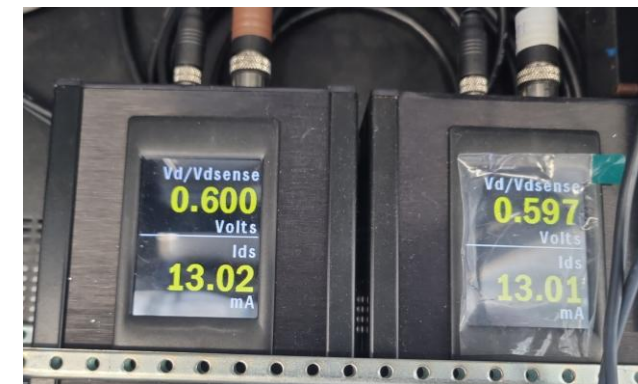
We bought 1 expensive calibrated Rox Sensor and used this to generate the calibration curves for several cheaper uncalibrated ones



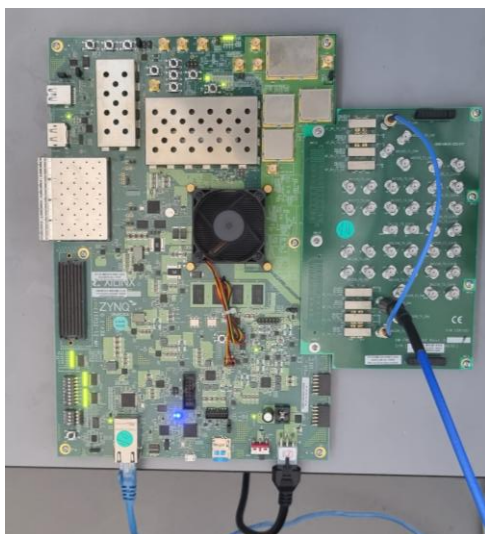
Lakeshore 372

Electronics

HEMT & PSUs



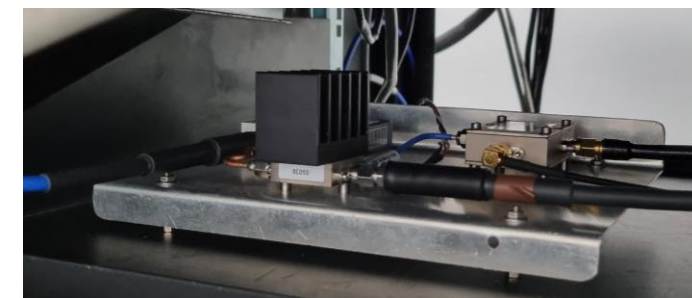
Fake axion injection signal
RFSoc - ZCU111



LNF 4-8GHz x 2 gives 39 dB gain each

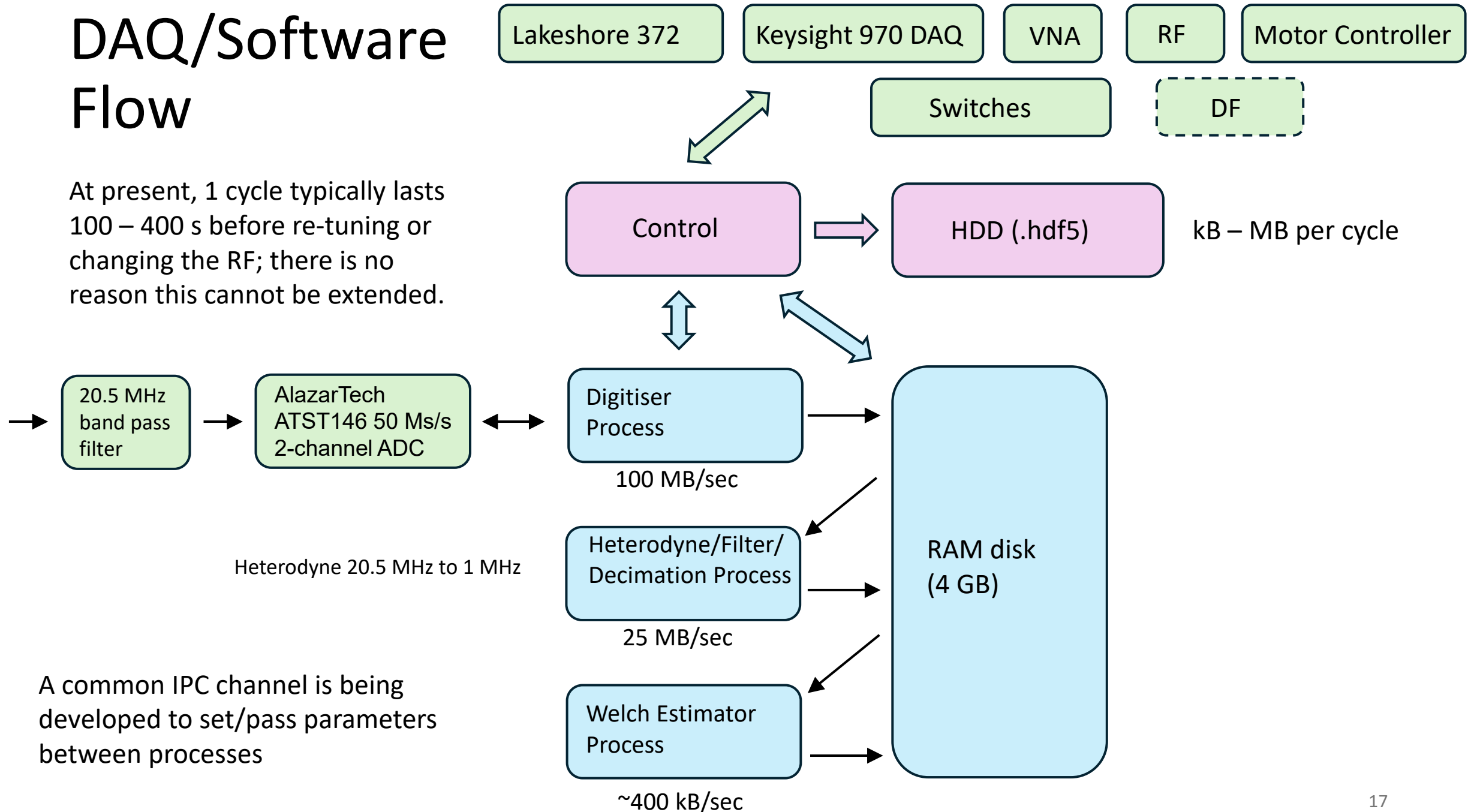
RT Amp, top of fridge gives ~40 dB

RF Mixer Amp – Heterodyne to 20.5 MHz



DAQ/Software Flow

At present, 1 cycle typically lasts 100 – 400 s before re-tuning or changing the RF; there is no reason this cannot be extended.



Instrumentation



- Network Switch/Frequency Ref
- RF Mixer
- 3 x Rohde Schwarz 12 GHz RF Sources
- Monitor for VNA
- Lakeshore 372AC Resistance Bridge
- Anritsu 20 GHz VNA
- Digitiser
- Keysight DAQ
- DAQ PC
- DC PSUs

Questions?