Search for Axion Dark Matter in a Mass Range of 6.62 to 7.04 μeV with a Tunable Microwave Resonant Cavity

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14th Patras Workshop on Axions, WIMPs and WISPs

Introduction to CAPP-8TB

- CAPP-8TB is an axion haloscope experiment at IBS/CAPP
  - Searches for 6.62 - 7.04 μeV (1.6 - 1.7 GHz) mass range
  - Aims to touch QCD axion band in the first stage
    - Utilizing HEMT (high electron mobility transistor) based low-noise amplifiers
    - Will take data for ~3 months
  - Targets KSVZ sensitivity in the later stage
    - Adopting SQUID-based amplifiers

CULTASK Refrigerators and Magnets

SQUID and Cavity R&D

Refrigerators

Vendor	Model	T_B (mK)	Cooling power	Installation
BlueFors (BF3)	LD400	10	18μW@20mK 580μW@100mK	2016
BlueFors (BF4)	LD400	10	18μW@20 580μW@100	2016
Janis	HE3	300	25μW@300mK	2017
BlueFors (BF5)	**LD400**	**10**	**18μW@20mK 580μW@100K**	**2017**
BlueFors (BF6)	LD400	10	18μW@20mK 580μW@100K	2017
Leiden	DRS1000	100	1mW @100mK	2018
Oxford	Kelvinox	<30	400 @120mK	2017

Magnets

B field	Bore (cm)	Material	Vendor	Delivery
26T	3.5	HTS	SUNAM	2016
18T	7	HTS	SUNAM	2017
9T	12	NbTi	Cryo-Magnetics	2017
8T	**12**	**NbTi**	**AMI**	**2016**
8T	16.5	NbTi	AMI	2017
25T	10	HTS	BNL/CAPP	2020
12T	32	Nb_3Sn	Oxford	2020

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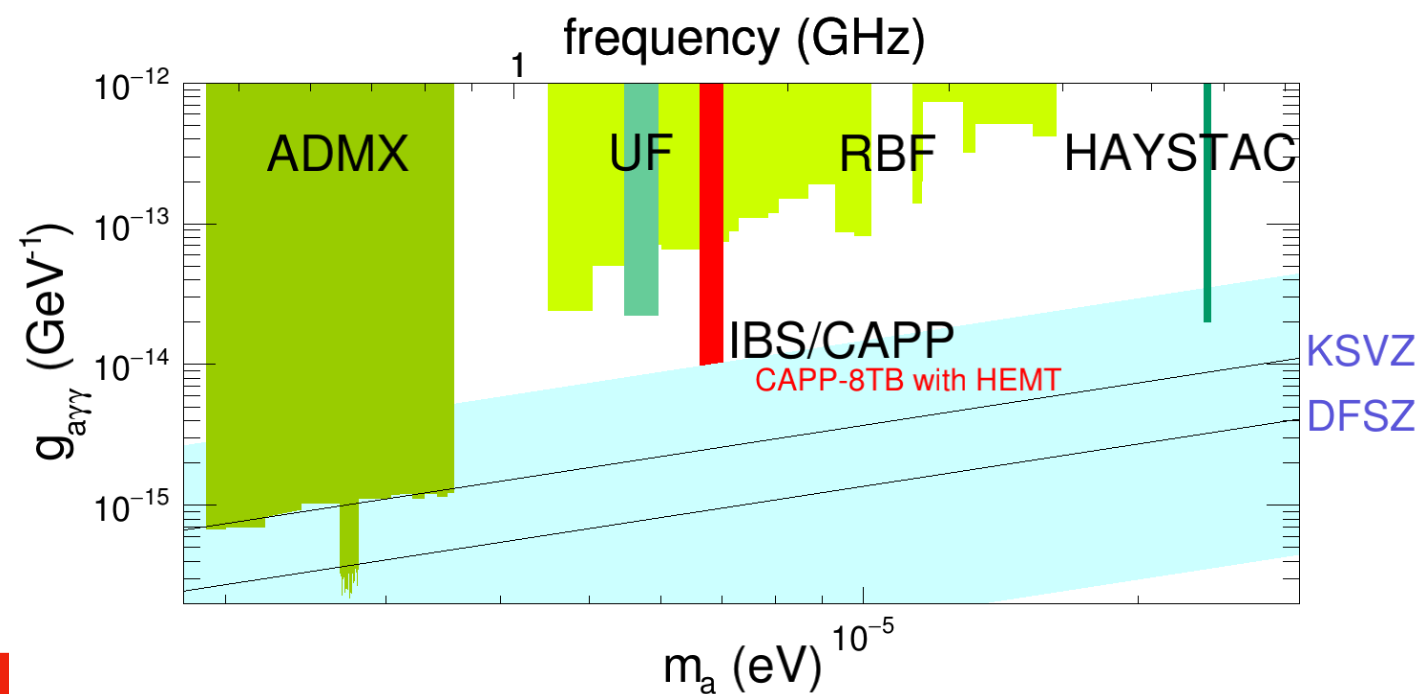
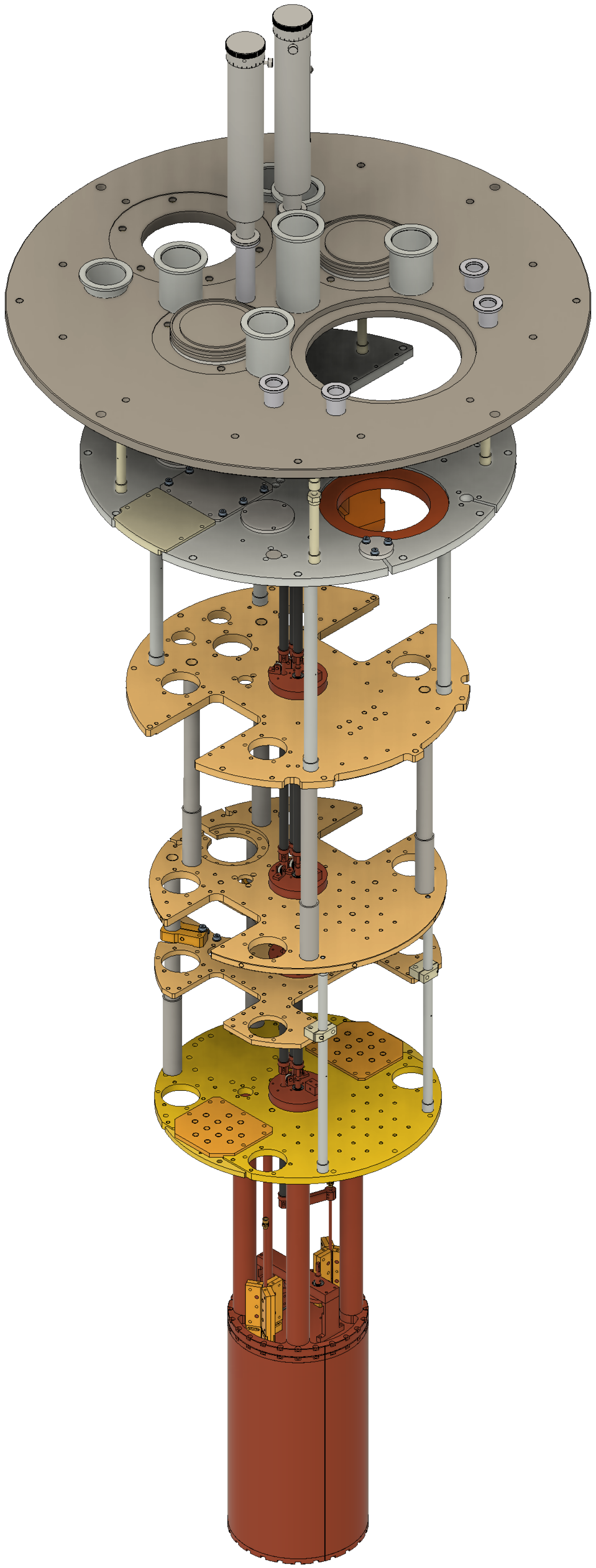
CAPP-8TB

W. Chung [Jun 19, 2018]

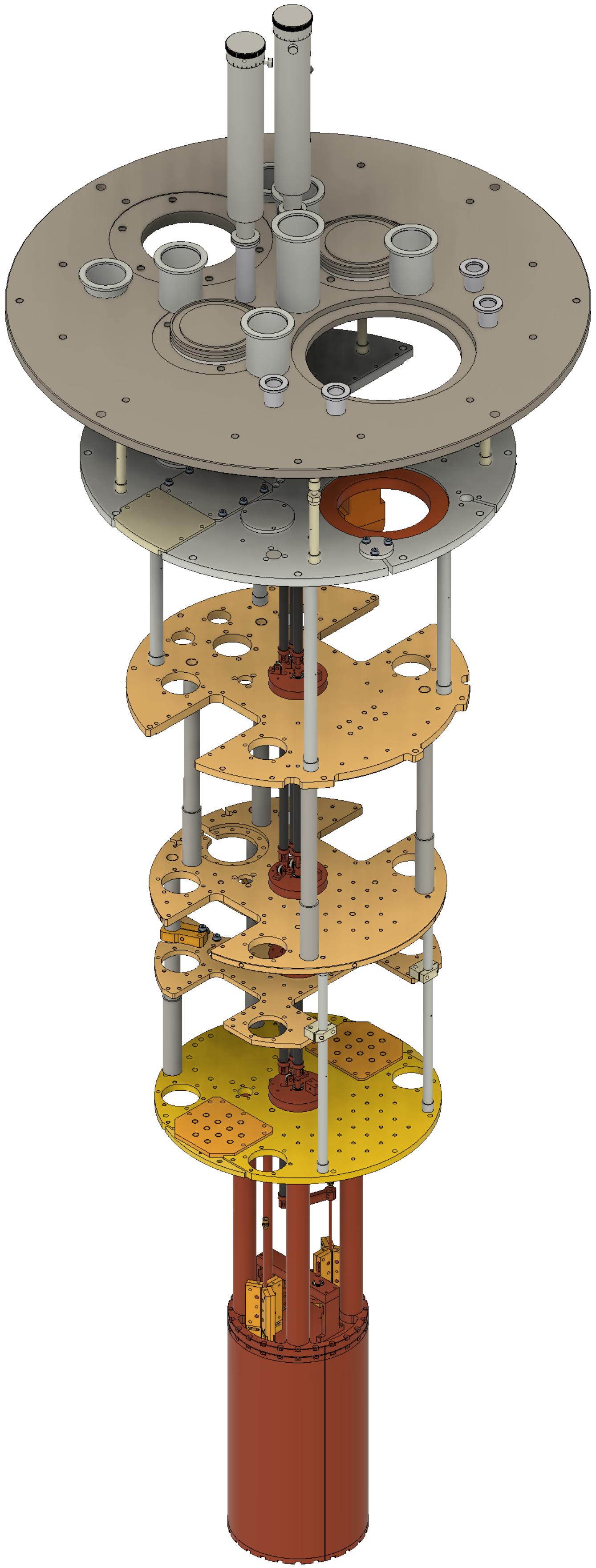


Parameters of the Experiment

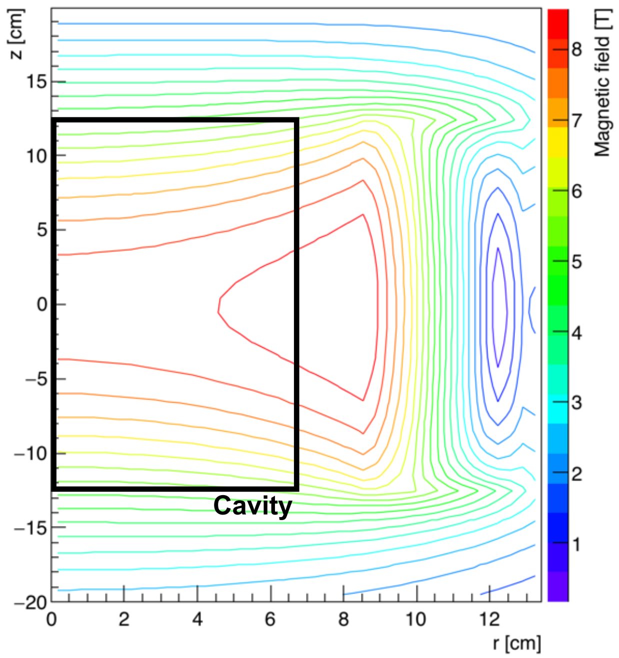


Parameters of the Experiment

$$\frac{df}{dt} \propto \frac{B^4 V^2 C_{010}^2 Q_L}{T^2}$$



Magnetic field map



AMI Superconducting magnet (8 T max.)
Average B field inside cavity volume: 7.3 T

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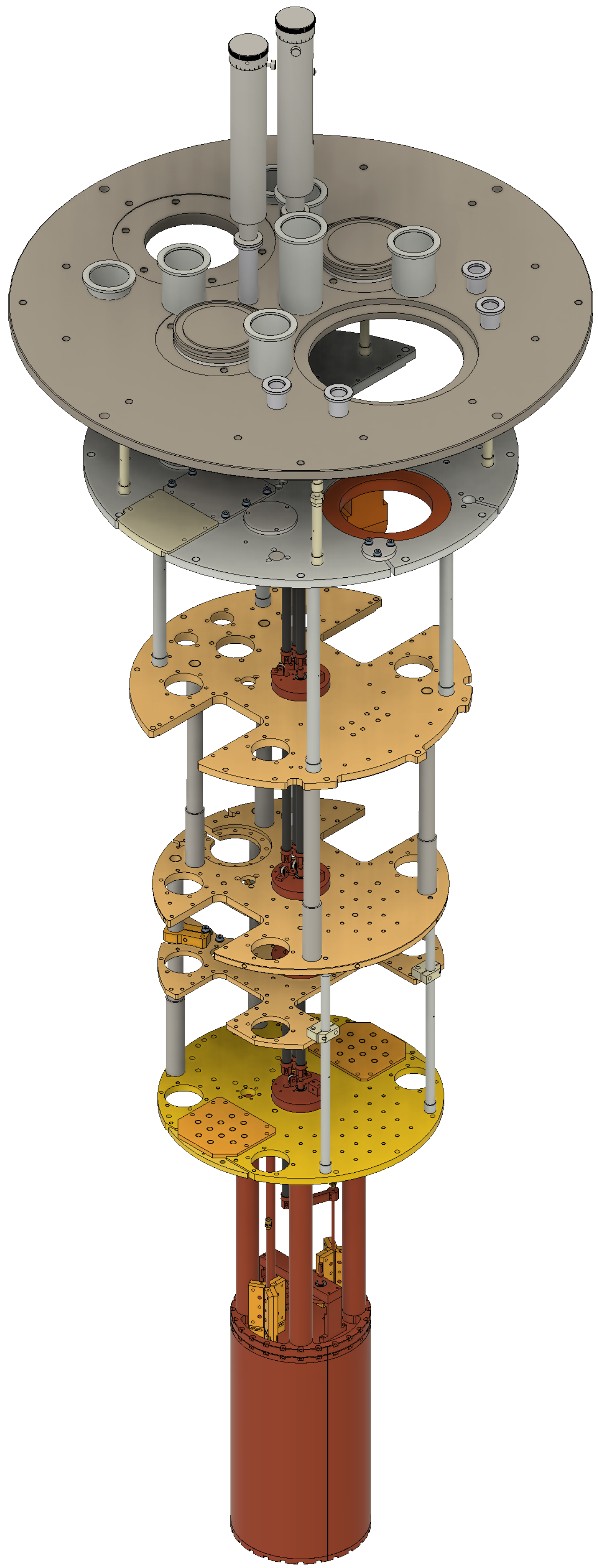

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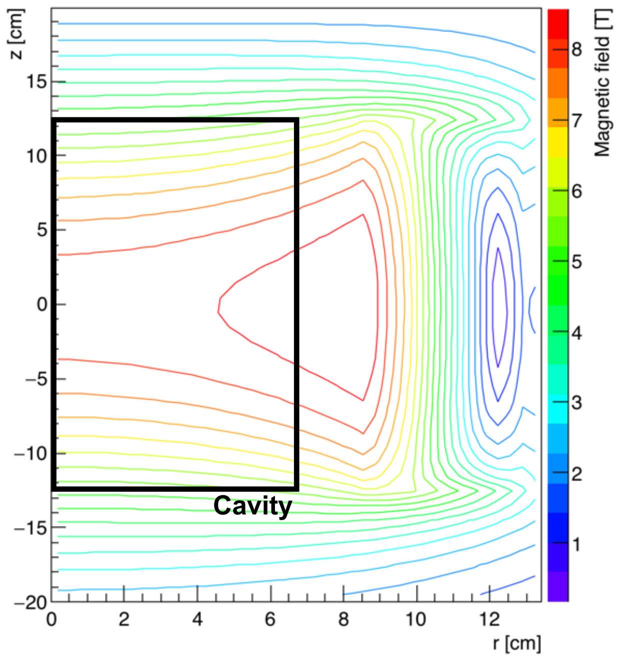

AMI Superconducting magnet (8 T max.)
Average B field inside cavity volume: 7.3 T

Inner diameter: 134 mm
Inner height: 236 mm
Inner volume: ~3.5 L

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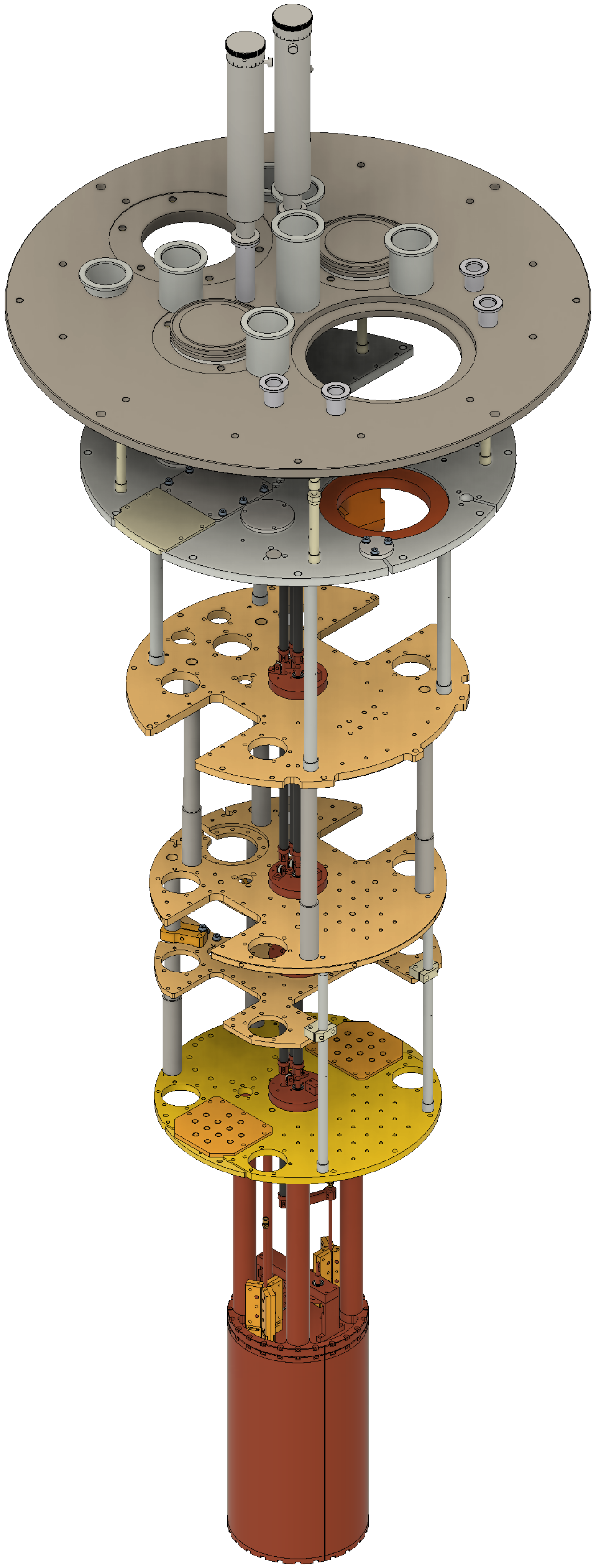

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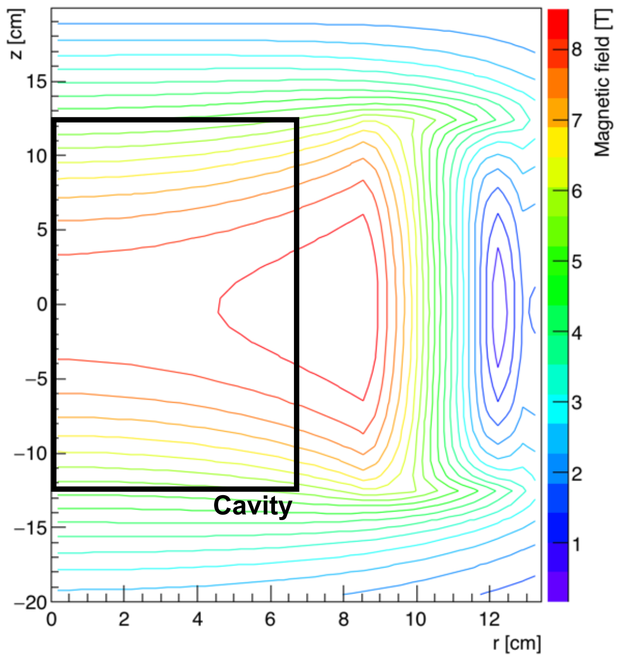

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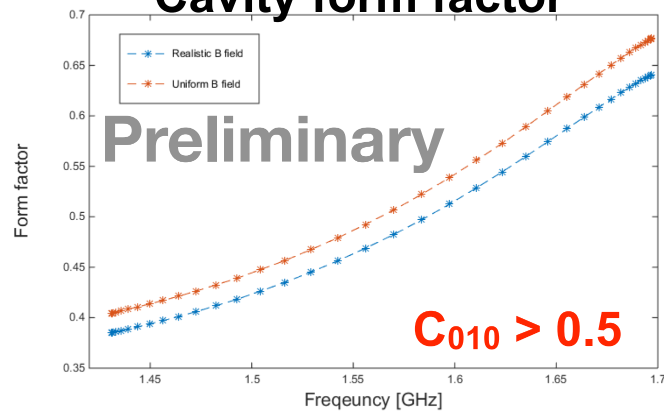
Cavity form factor



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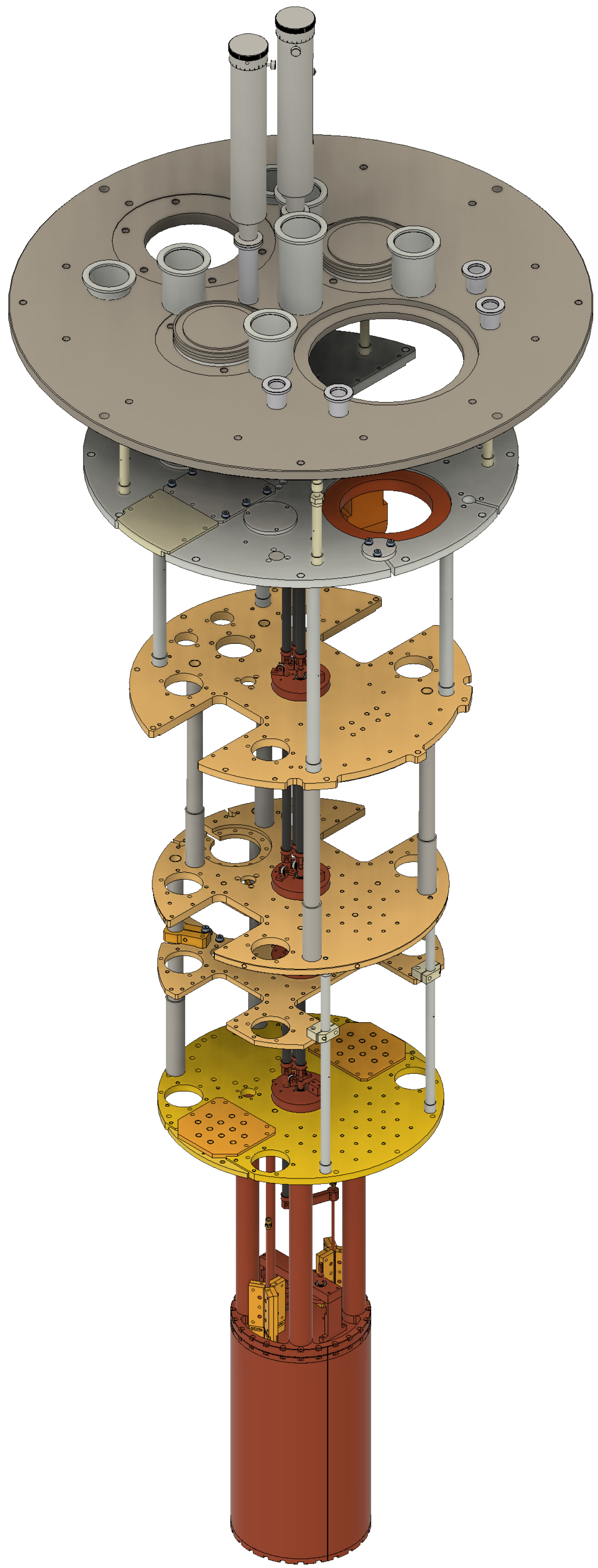
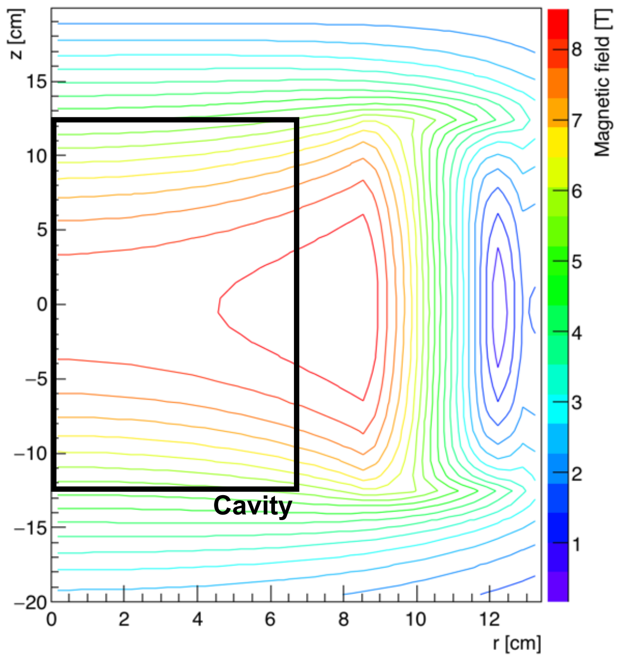


Parameters of the Experiment

Magnetic field map



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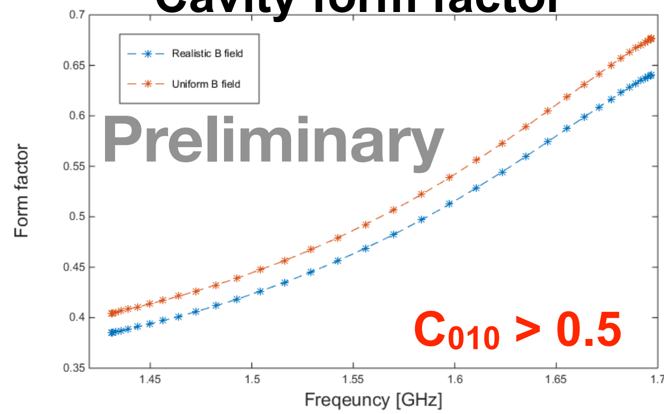

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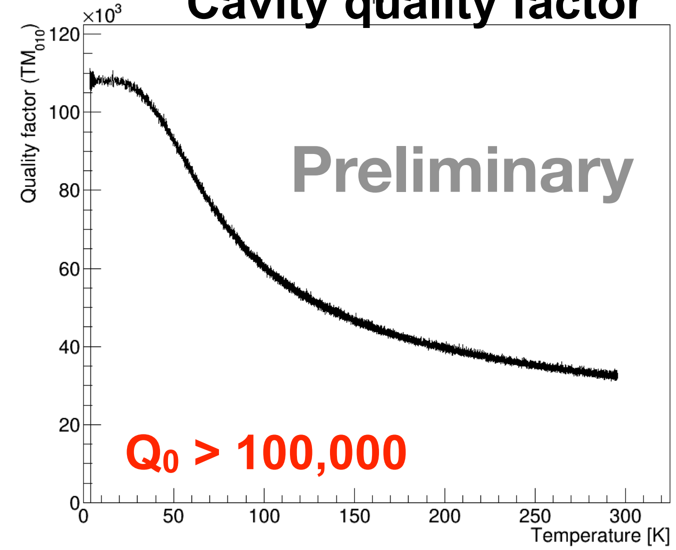
Cavity quality factor



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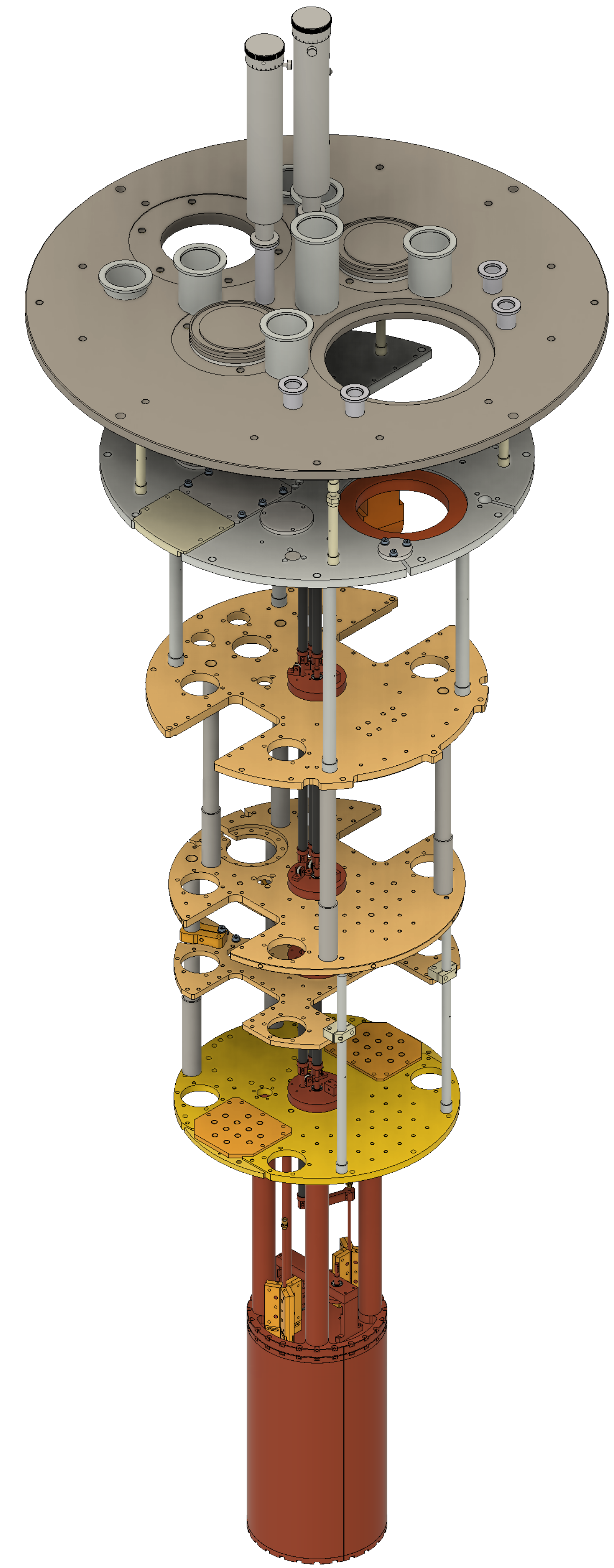

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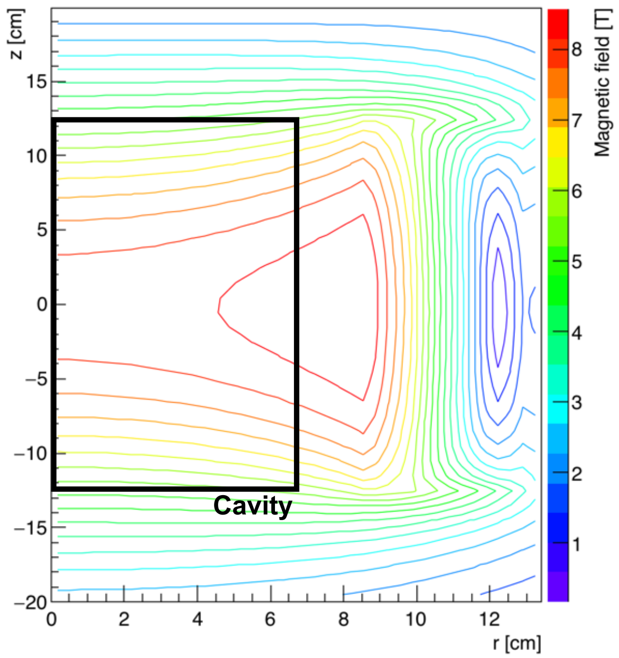

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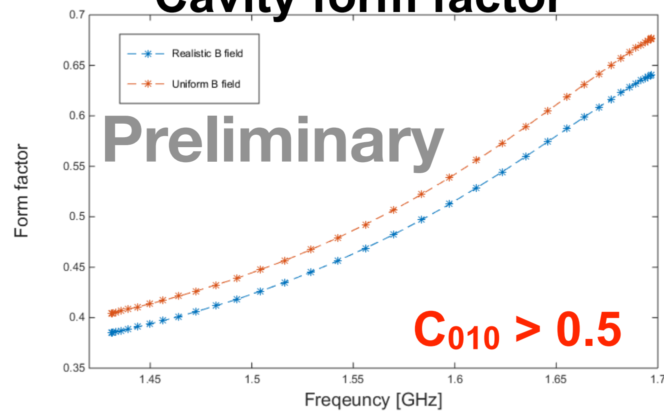

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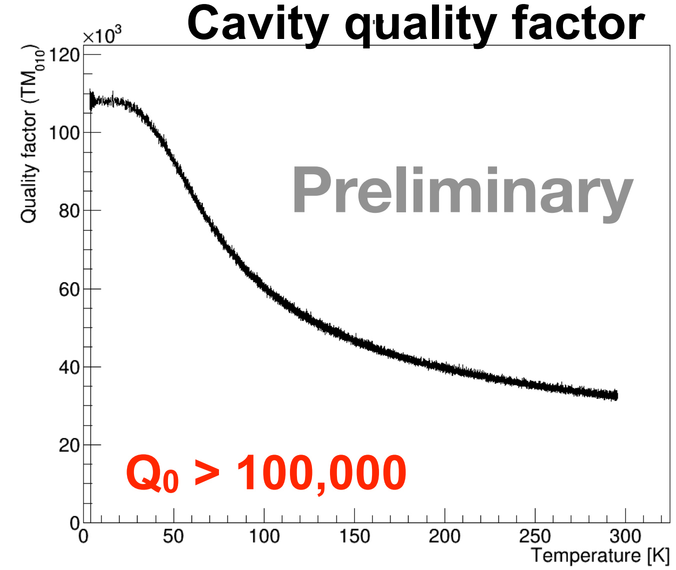
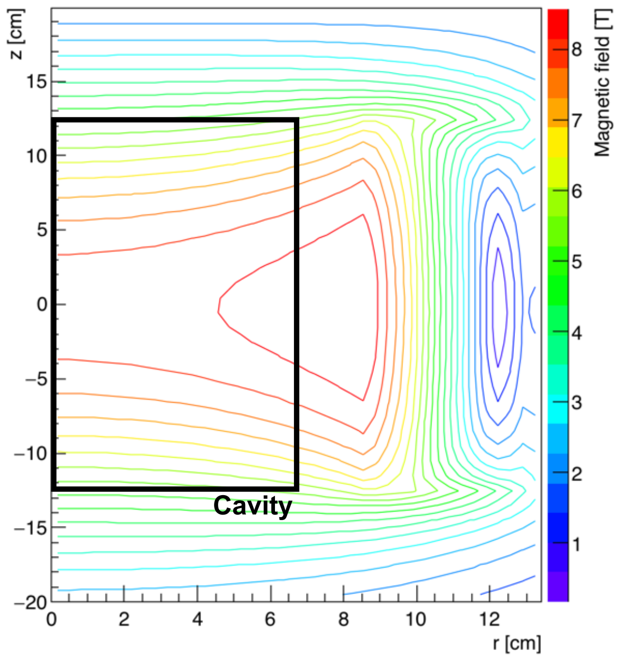


$$\frac{df}{dt} \propto \frac{B^4 V^2 C_{010}^2 Q_L}{T^2}$$

Cavity physical temperature: < 40 mK
Tuning rod physical temperature: < 150 mK

Parameters of the Experiment

Magnetic field map



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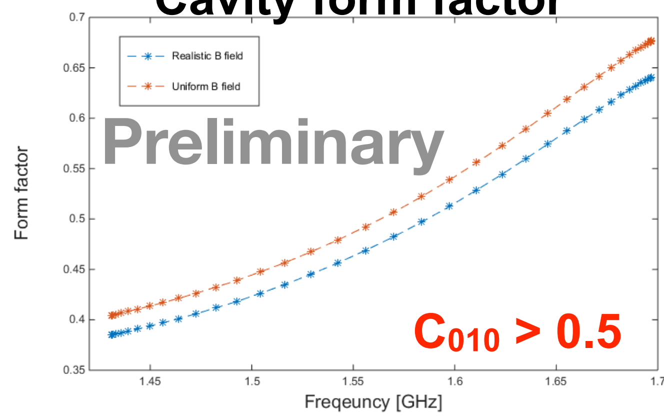

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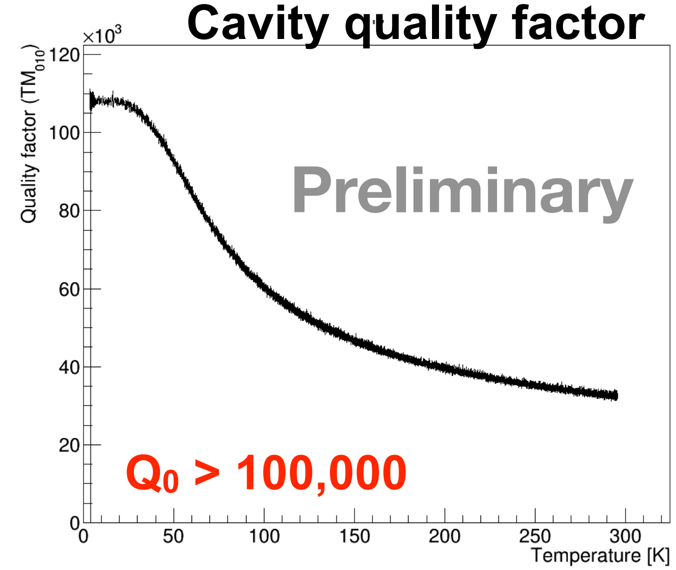

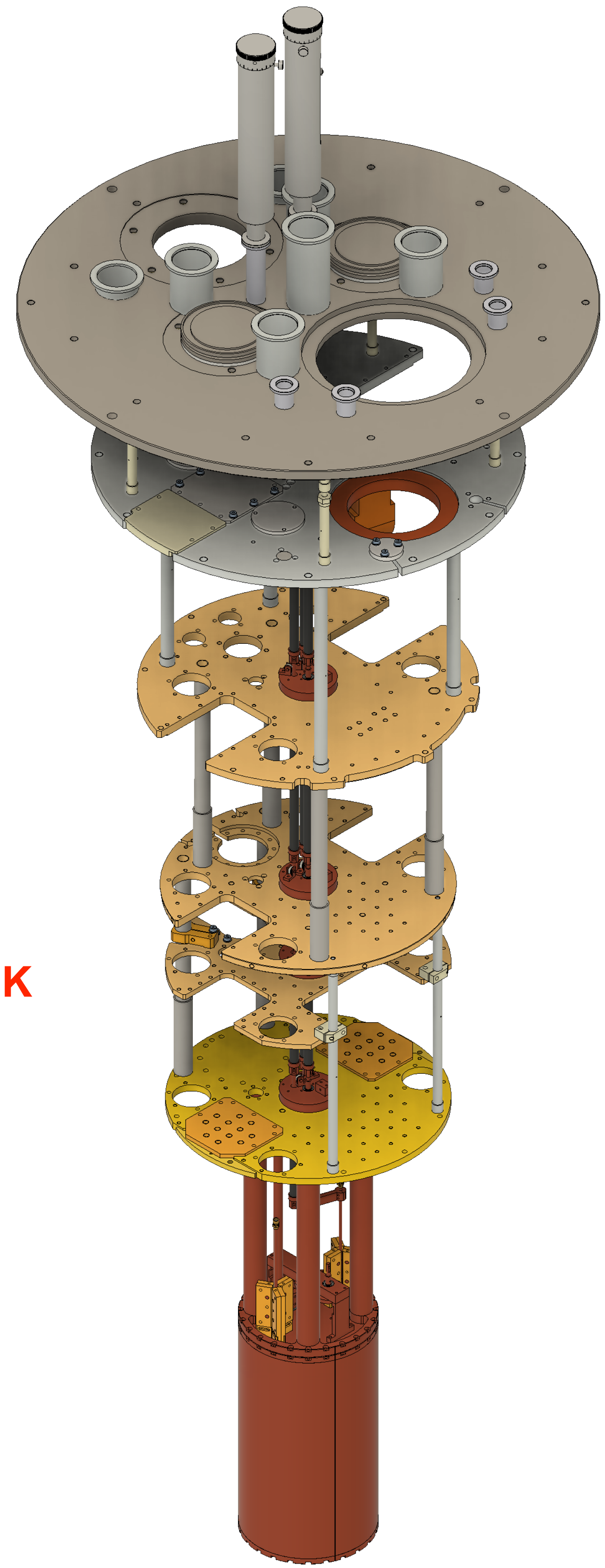

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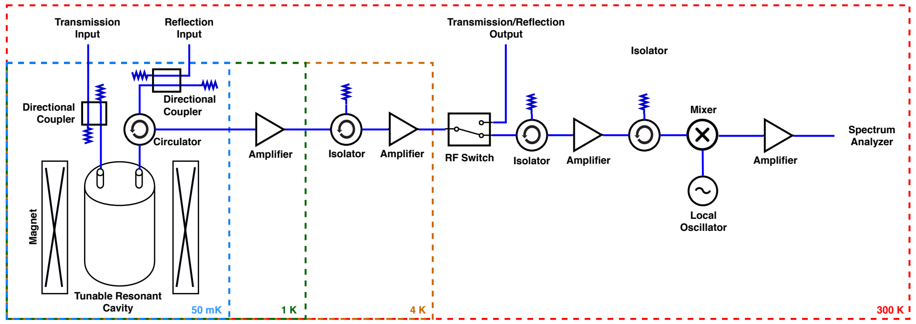
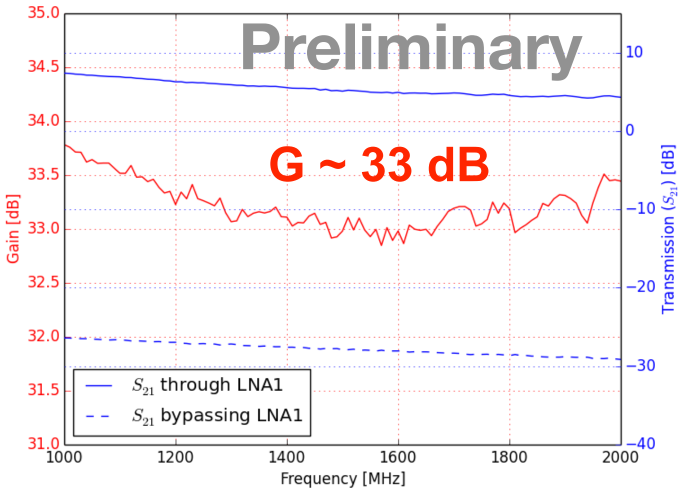
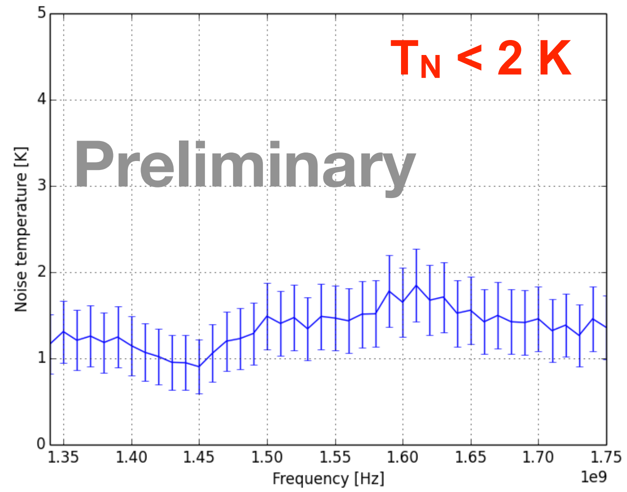


Gain (left) and noise temperature (right) of the 1st amplifier





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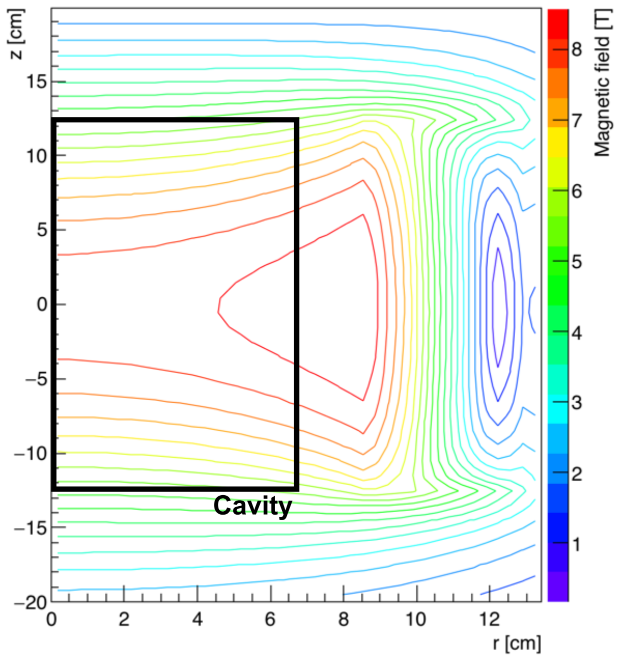

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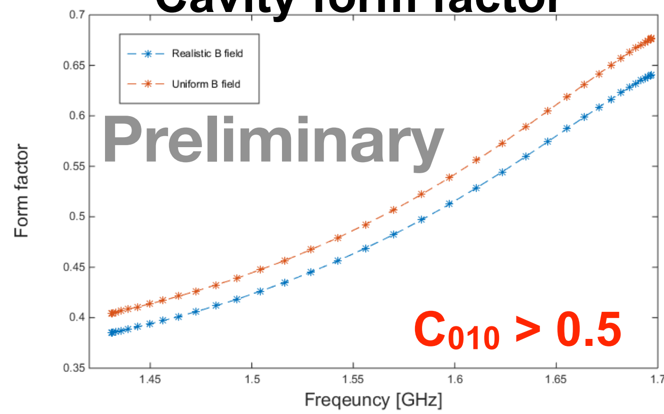

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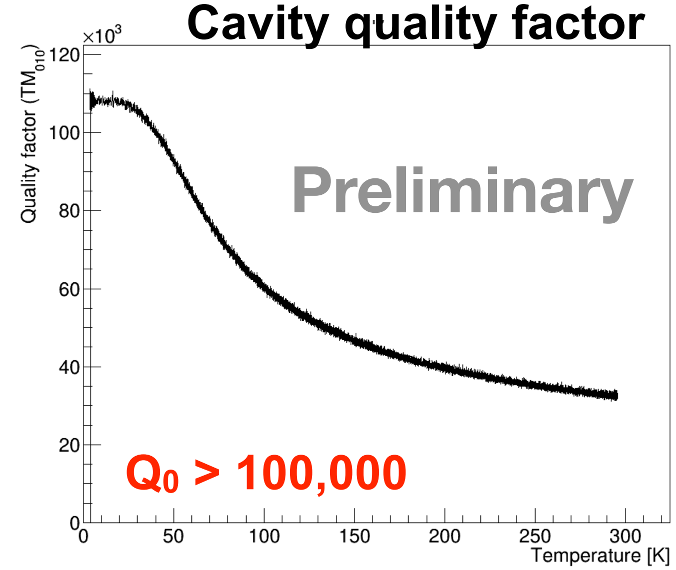

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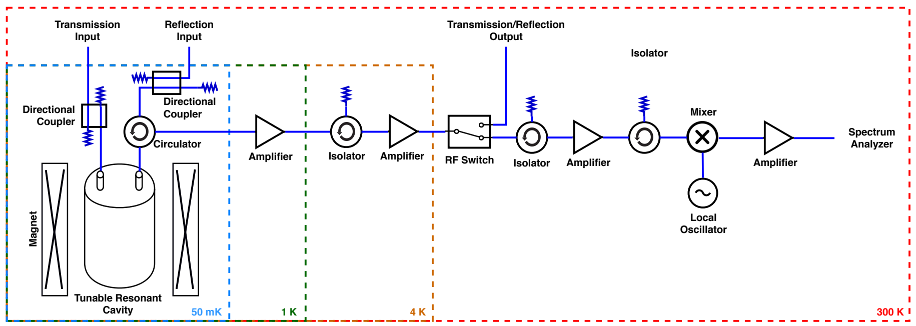

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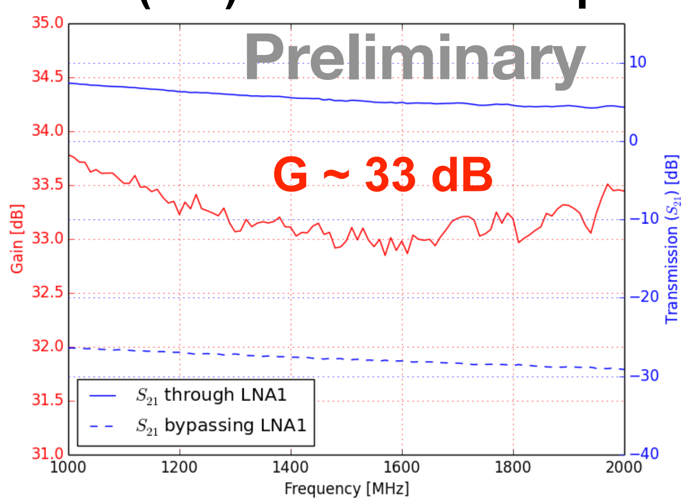
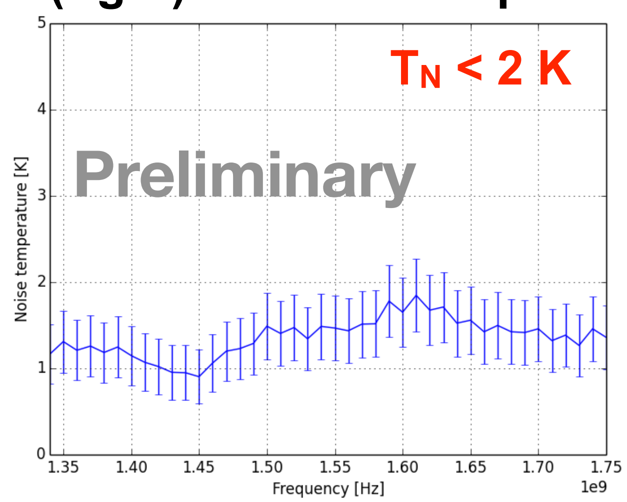
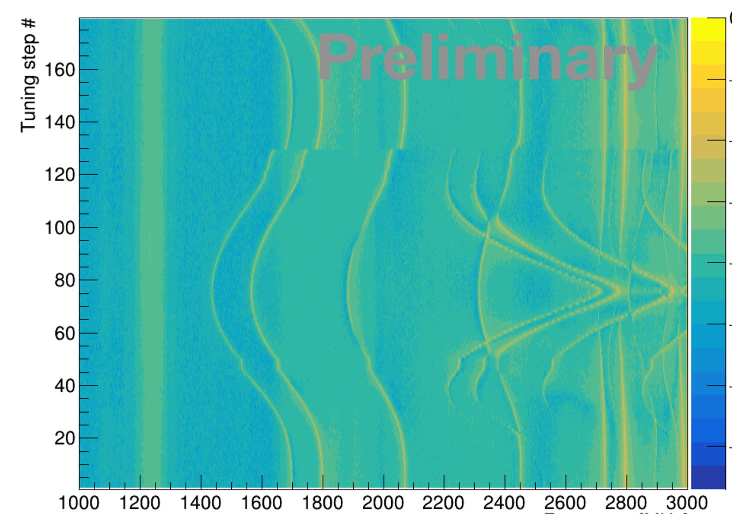


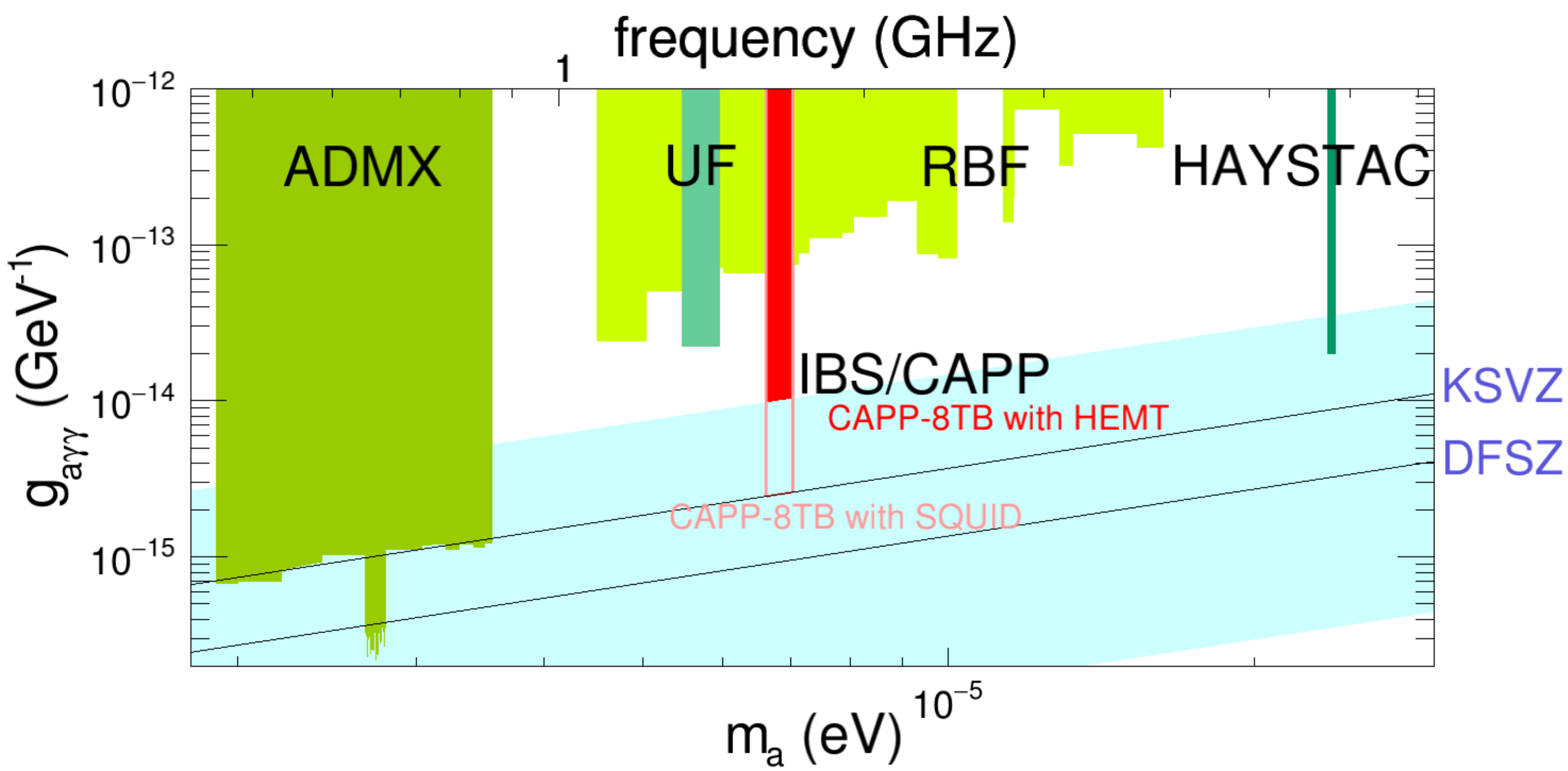


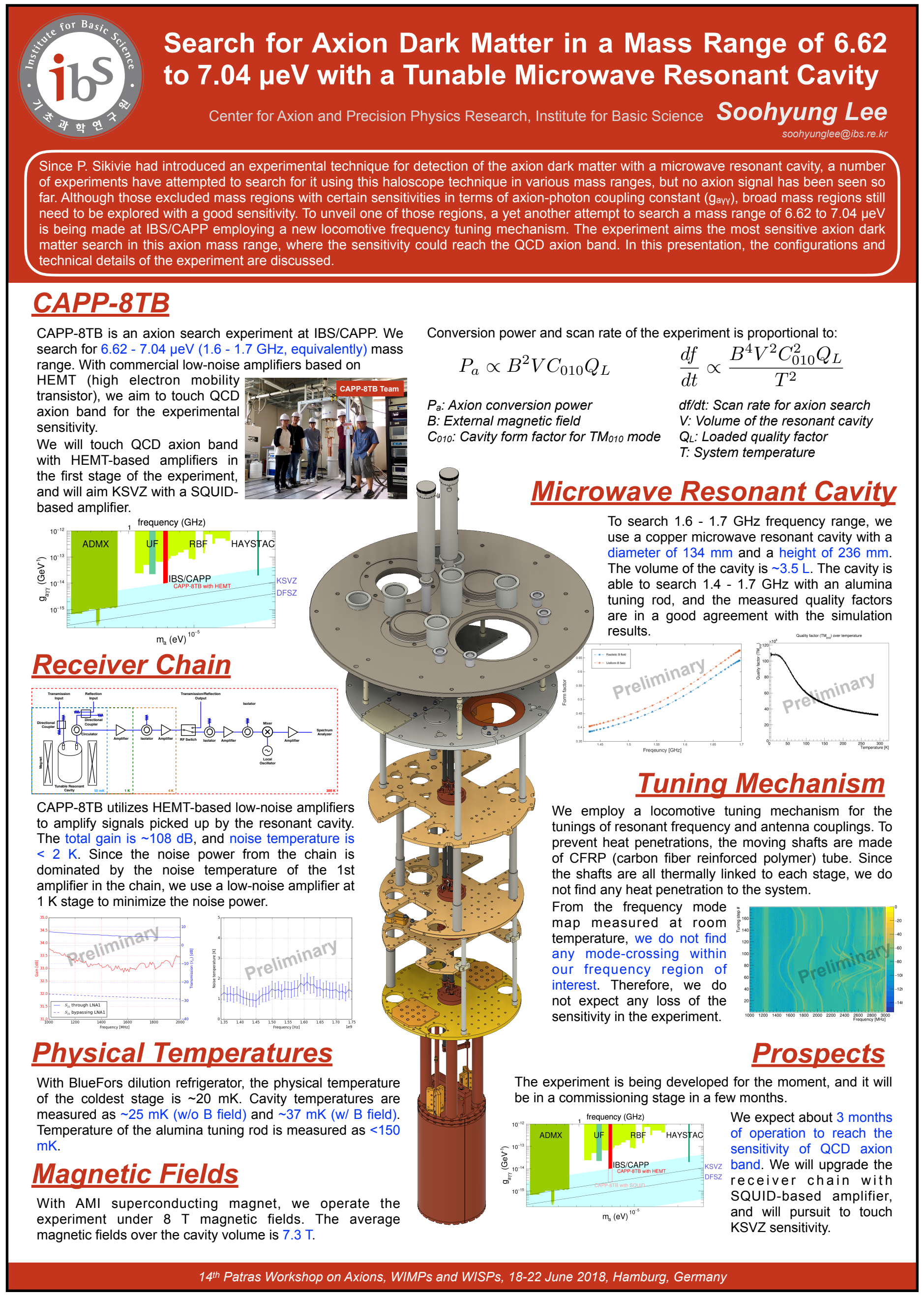


No mode-crossings

Prospects

- 1st stage: w/ HEMT-based amplifier (~3 months of operation)
  - Touching QCD axion band
  - Expected commissioning in a few months
- 2nd stage: w/ SQUID-based amplifier
  - Reach to KSVZ sensitivity





Search for Axion Dark Matter in a Mass Range of 6.62 to 7.04 μeV with a Tunable Microwave Resonant Cavity

Center for Axion and Precision Physics Research, Institute for Basic Science **Soohyung Lee**
soohyunglee@ibs.re.kr

Since P. Sikivie had introduced an experimental technique for detection of the axion dark matter with a microwave resonant cavity, a number of experiments have attempted to search for it using this haloscope technique in various mass ranges, but no axion signal has been seen so far. Although those excluded mass regions with certain sensitivities in terms of axion-photon coupling constant ($g_{a\gamma\gamma}$), broad mass regions still need to be explored with a good sensitivity. To unveil one of those regions, a yet another attempt to search a mass range of 6.62 to 7.04 μeV is being made at IBS/CAPP employing a new locomotive frequency tuning mechanism. The experiment aims the most sensitive axion dark matter search in this axion mass range, where the sensitivity could reach the QCD axion band. In this presentation, the configurations and technical details of the experiment are discussed.

CAPP-8TB

CAPP-8TB is an axion search experiment at IBS/CAPP. We search for 6.62 - 7.04 μeV (1.6 - 1.7 GHz, equivalently) mass range. With commercial low-noise amplifiers based on HEMT (high electron mobility transistor), we aim to touch QCD axion band for the experimental sensitivity.

We will touch QCD axion band with HEMT-based amplifiers in the first stage of the experiment, and will aim KSVZ with a SQUID-based amplifier.

CAPP-8TB Team

Conversion power and scan rate of the experiment is proportional to:

$$P_a \propto B^2 V C_{010} Q_L \qquad \frac{df}{dt} \propto \frac{B^4 V^2 C_{010}^2 Q_L}{T^2}$$

P_a: Axion conversion power
B: External magnetic field
C_{010}: Cavity form factor for TM_{010} mode
df/dt: Scan rate for axion search
V: Volume of the resonant cavity
Q_L: Loaded quality factor
T: System temperature

Microwave Resonant Cavity

To search 1.6 - 1.7 GHz frequency range, we use a copper microwave resonant cavity with a diameter of 134 mm and a height of 236 mm. The volume of the cavity is ~3.5 L. The cavity is able to search 1.4 - 1.7 GHz with an alumina tuning rod, and the measured quality factors are in a good agreement with the simulation results.

Receiver Chain

CAPP-8TB utilizes HEMT-based low-noise amplifiers to amplify signals picked up by the resonant cavity. The total gain is ~108 dB, and noise temperature is < 2 K. Since the noise power from the chain is dominated by the noise temperature of the 1st amplifier in the chain, we use a low-noise amplifier at 1 K stage to minimize the noise power.

Tuning Mechanism

We employ a locomotive tuning mechanism for the tunings of resonant frequency and antenna couplings. To prevent heat penetrations, the moving shafts are made of CFRP (carbon fiber reinforced polymer) tube. Since the shafts are all thermally linked to each stage, we do not find any heat penetration to the system.

From the frequency mode map measured at room temperature, we do not find any mode-crossing within our frequency region of interest. Therefore, we do not expect any loss of the sensitivity in the experiment.

Physical Temperatures

With BlueFors dilution refrigerator, the physical temperature of the coldest stage is ~20 mK. Cavity temperatures are measured as ~25 mK (w/o B field) and ~37 mK (w/ B field). Temperature of the alumina tuning rod is measured as <150 mK.

Magnetic Fields

With AMI superconducting magnet, we operate the experiment under 8 T magnetic fields. The average magnetic fields over the cavity volume is 7.3 T.

Prospects

The experiment is being developed for the moment, and it will be in a commissioning stage in a few months.

We expect about 3 months of operation to reach the sensitivity of QCD axion band. We will upgrade the receiver chain with SQUID-based amplifier, and will pursuit to touch KSVZ sensitivity.

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