IBS - Dark Matter Axion Group (DMAG)
Daejeon, South Korea

KPS Fall 2025
22-24 APRIL
2025

Dark Matter Axion Group (DMAG) – 8T (DMAG-8T) with *High-Temperature Superconducting* Cavity

24th Oct 2025

JIWON LEE , DANHO AHN, OHJOON KWON

Contents

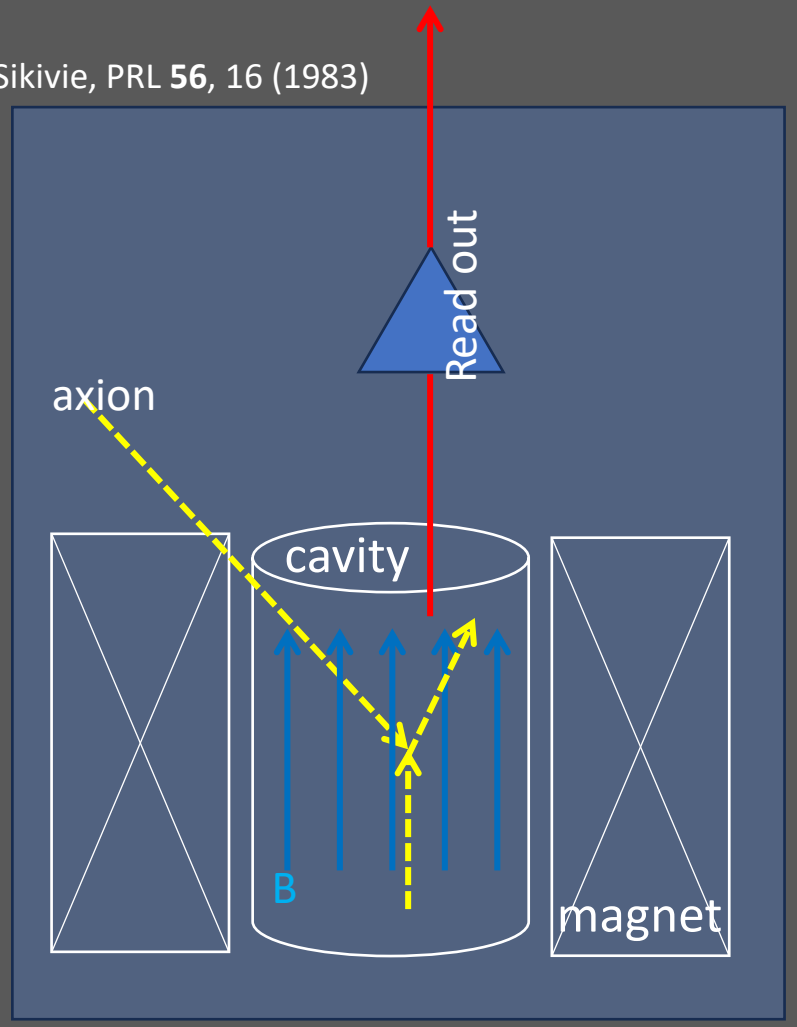
- Axion haloscope
- Dark Matter Axion Group – 8T (DMAG-8T)
  - Dark matter axion search around 5.4GHz using >3M Q-factor HTS cavity
  - 3.7-3.95GHz axion search with HTS cavity
- Summary & Future plan

Axion haloscope

→ The most sensitive method for detecting axion dark matter

D. kim, et al, JCAP03(2020)066

P. Sikivie, PRL **56**, 16 (1983)



$$P_{sig} = g_{a\gamma\gamma}^2 \frac{\rho_a}{m_a} \frac{\beta}{1+\beta} B^2 V C Q_{all}$$

$$\frac{1}{Q_{all}} = \frac{1}{Q_0} + \frac{1}{Q_{ext}} + \frac{1}{Q_a} = \frac{Q_L + Q_a}{Q_L Q_a}$$

$$\frac{df}{dt} \propto B^4 V^2 \frac{C^2 Q_{all}}{T_{sys}^2}$$

Predecided (infra limited)

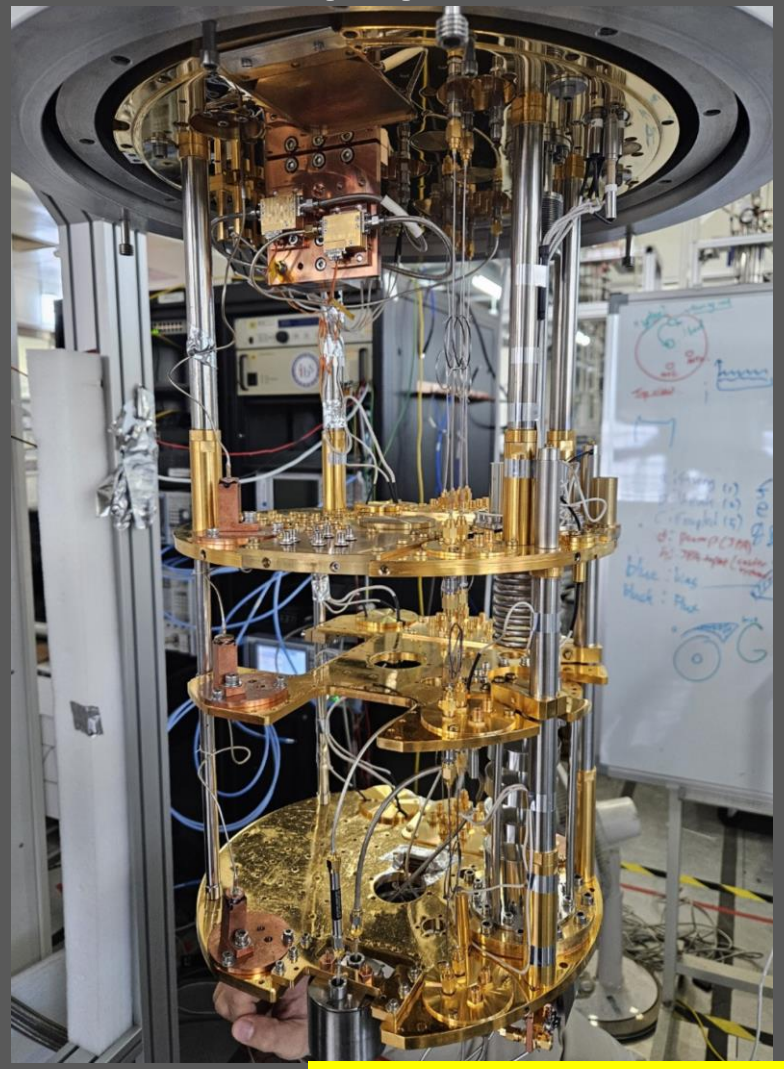
The magnet is built by an external company.

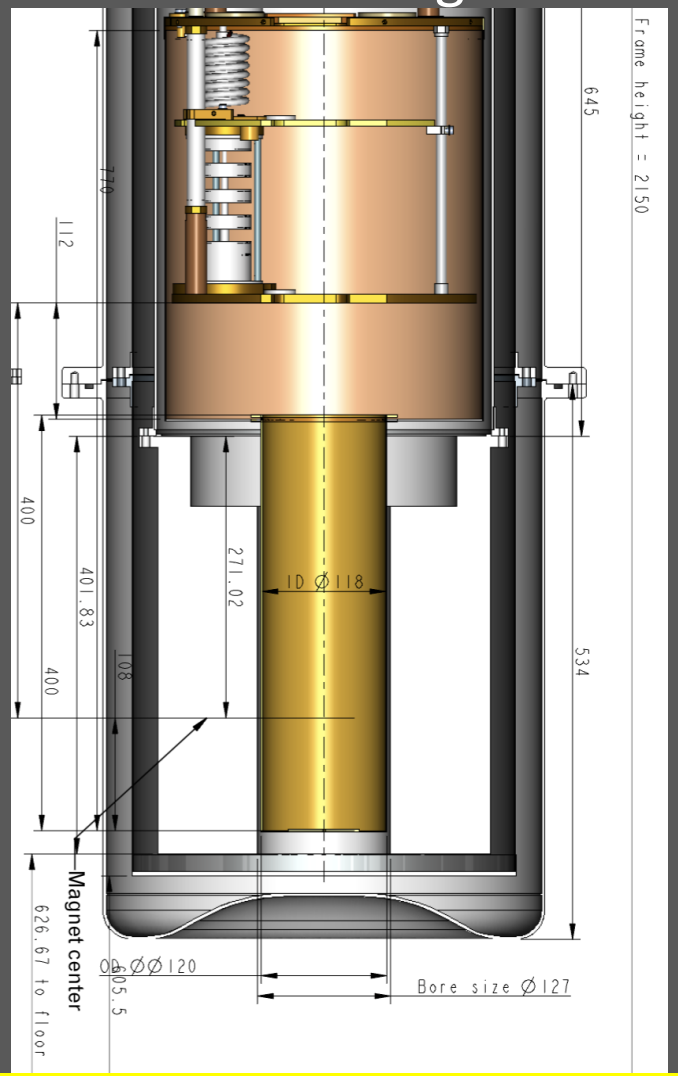
R&D achievement

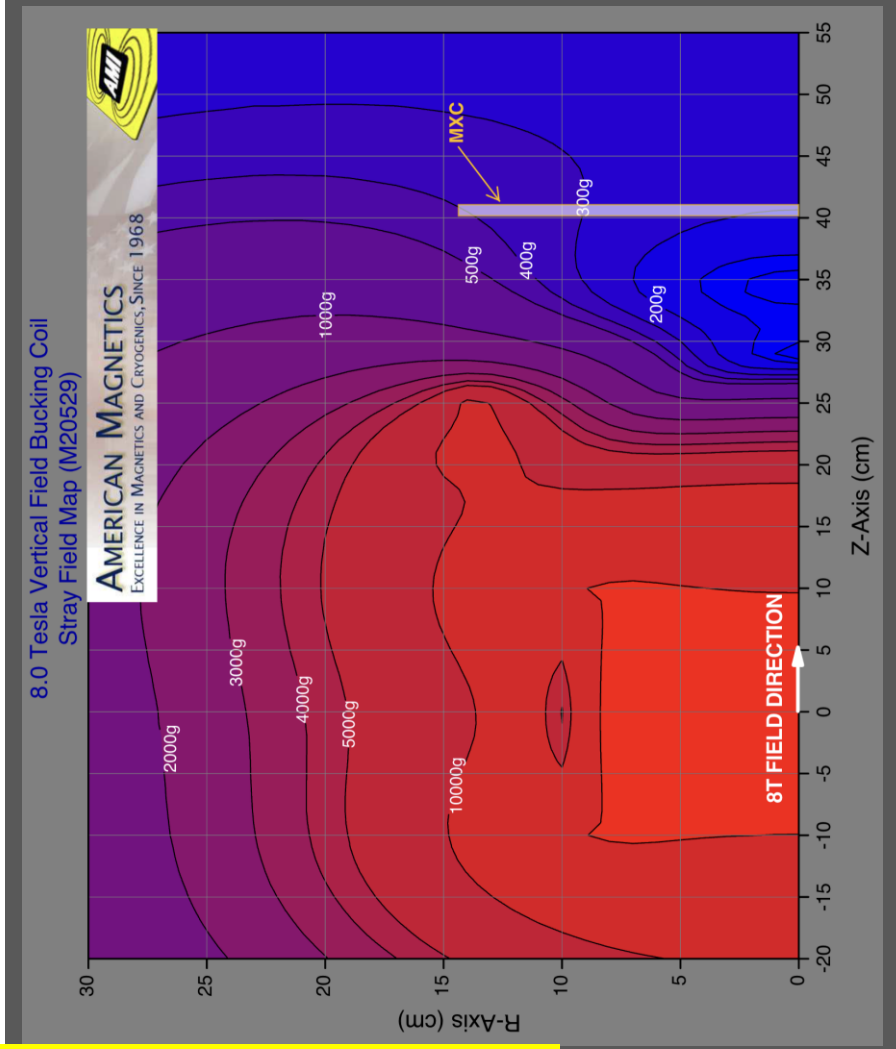
DMAG HTS team

Dark Matter Axion Group (DMAG) - 8T

- ***Equipment*** : Bluefors dilution refrigerator LD400 + AMI 8T, 12cm bore magnet







It allows us to perform sub-Kelvin measurements in a high magnetic field environment.

Dark Matter Axion Group (DMAG) - 8T

- ***People***

- Ohjoon Kwon
- Jiwon Lee
- Danho Ahn (left for Italy)

+ w/ help of all DMAG members

Experimental Goal

Cavity design

Constraints:

Inner bore: 118mm

Magnet center to bottom of still shield: 108mm

Considering these limits,

➔ Cavity volume < 2L

w/ $B_{average}$ = 7-7.5 T

Experimental Goal

Target experimental performance

KSVZ axion search >300MHz/year, ~2 GHz/5year

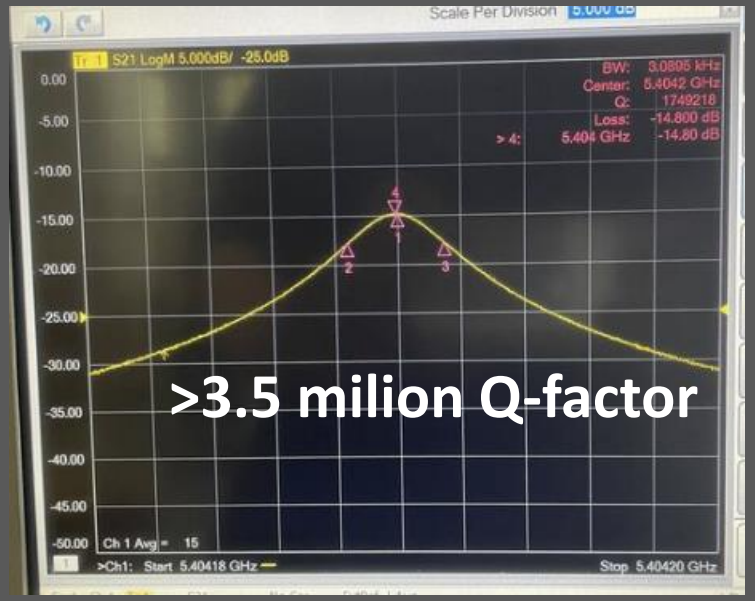
Average B-field:	7-7.3T
Cavity volume:	1.5-1.9L
Q-factor:	500k – 2M
Form factor:	0.5-0.7
Noise temperature:	0.25-0.5K

0.5-5MHz/day

DMAG-8T-5.4GHz experiment

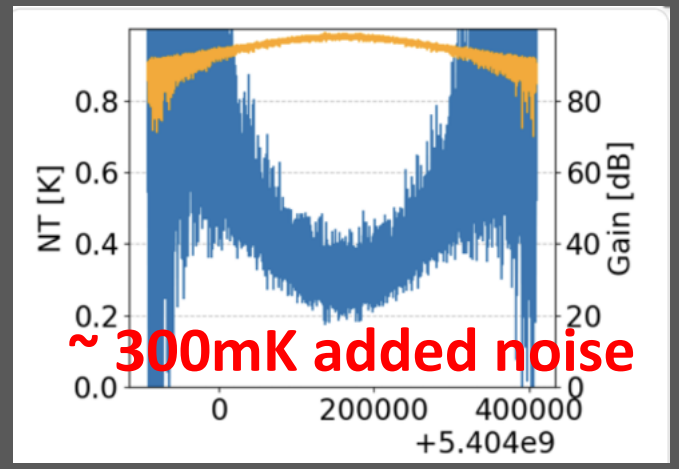
- The **highest Q-factor** cavity among all the DMAG's HTS cavities
- Flux-driven JPA from RIKEN (Int'l collaboration w/ Nakamura's group)

5.4GHz HTS cavity



VNA screen measuring Q-factor

JPA packaged in DMAG



Noise measurement of 5.4GHz JPA

3M cavity photo + Q _plot

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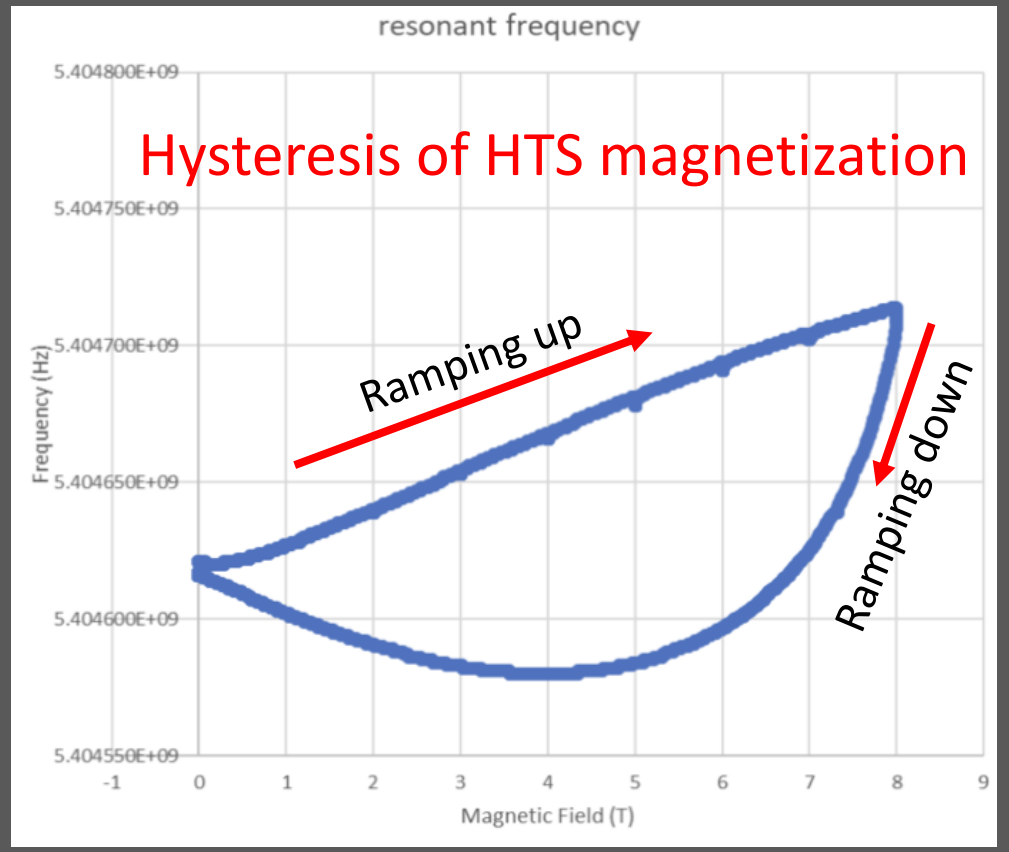
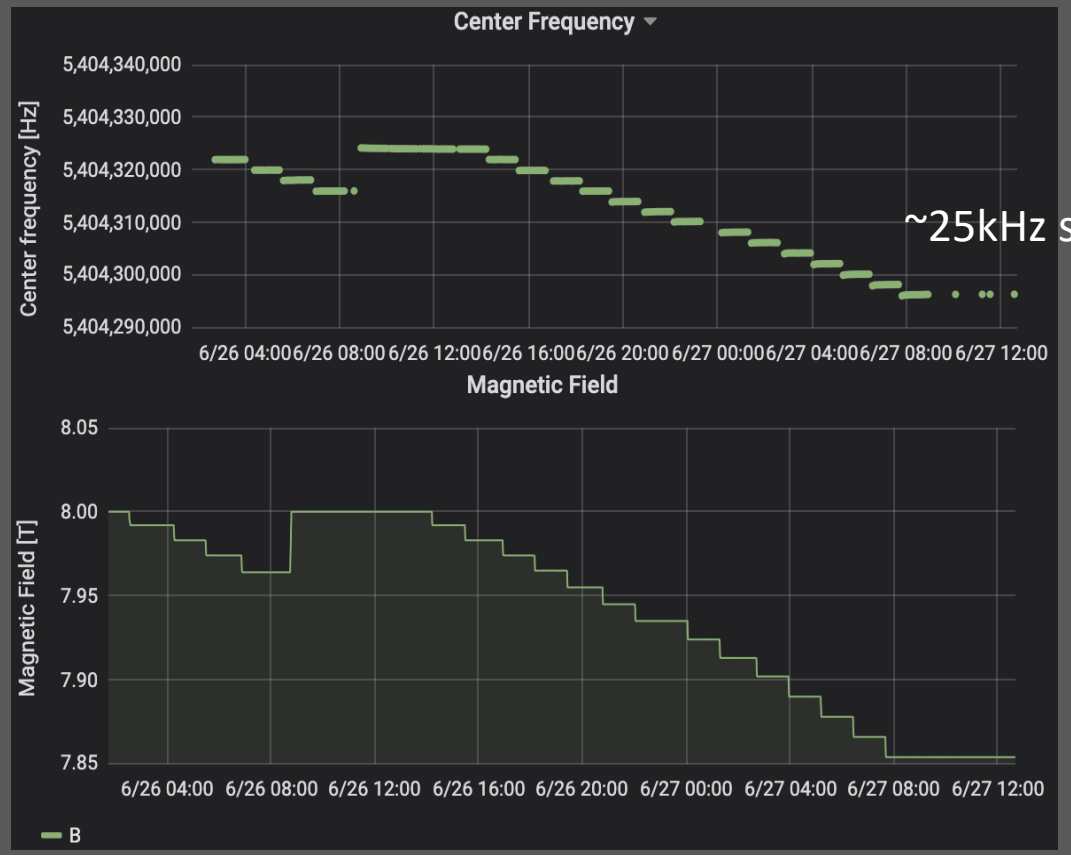
DMAG-8T-5.4GHz experiment

- ***Frequency tuning using HTS magnetization***

No tuning rod inside!!





~25kHz scanned

B: 8T → 7.85T, Frequency change: 25kHz

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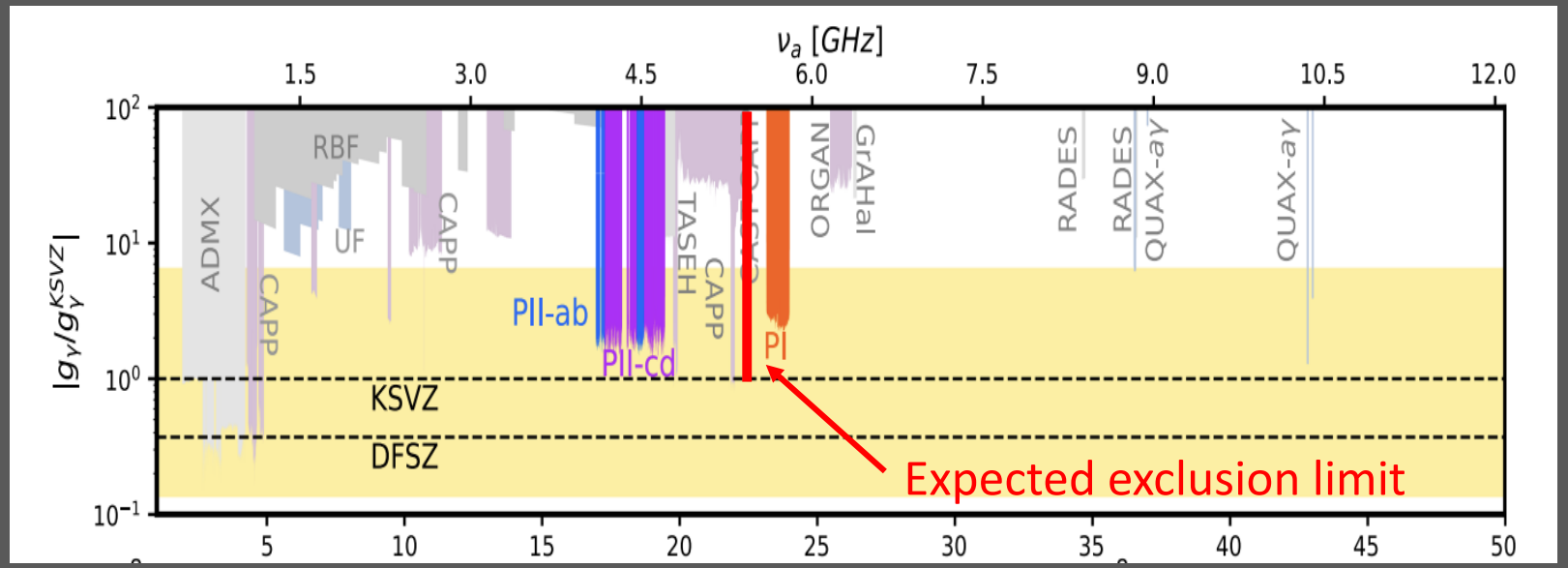
DMAG-8T-5.4GHz experiment

- Physics run performed by Dr. Danho Ahn

Conditions of our physics run

Parameter	Value
B_ave (T)	7.7
Cavity volume (L)	0.2
Loaded Q-factor	1.8M
Coupling strength	1
Frequency (GHz)	5.4043 GHz
Form factor	0.65
System noise (T)	0.4

25-06-26 12:00 – 25-06-27 09:00 21 hours



KSVZ axion scan rate:

8Hz/s, 0.07MHz/day

Detailed analysis is ongoing

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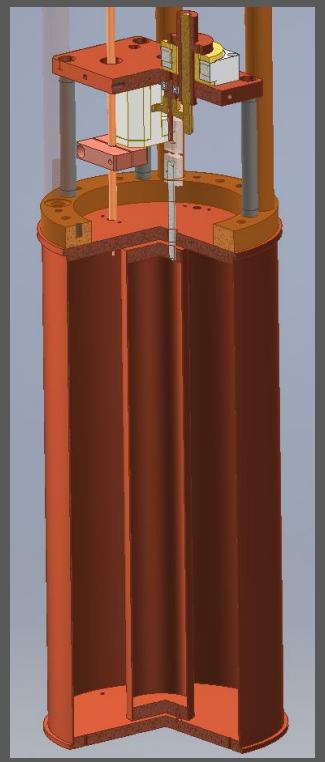
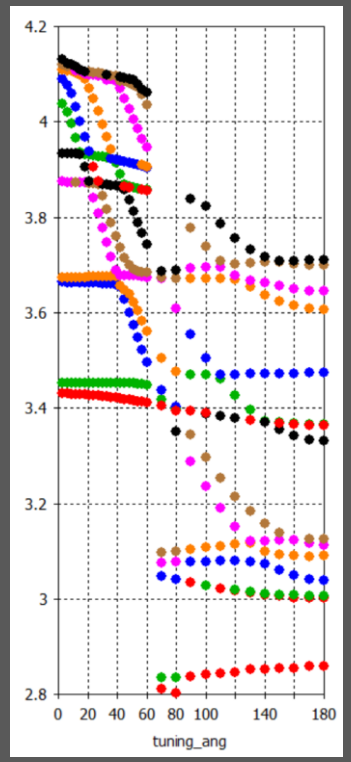
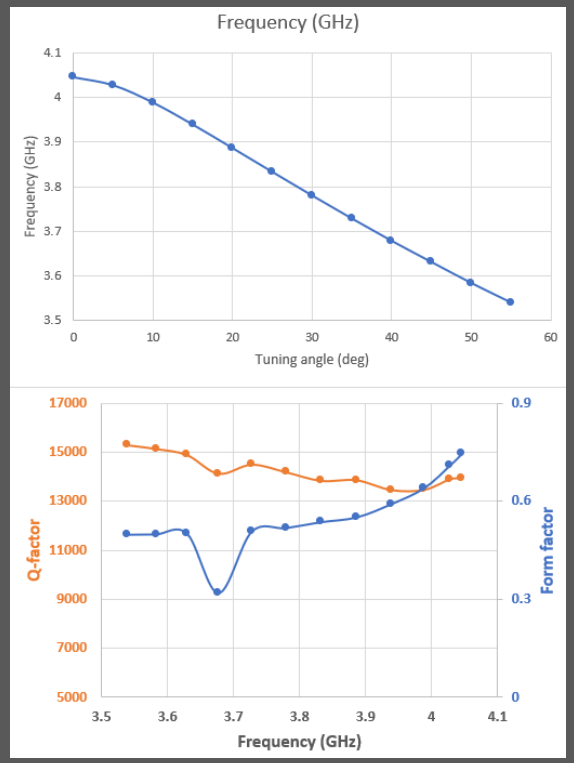
DMAG-8T-4GHz experiment

- **3.6-4GHz** axion search using HTS cavity.
- Flux-driven JPA from RIKEN (Int'l collaboration w/ Nakamura's group)

3.6-4GHz HTS Cavity







3.7-4GHz JPA tested by Sergey

- ~1.5 quanta of T_{sys}? (~300mK)

(half quanta ~ 95mK)

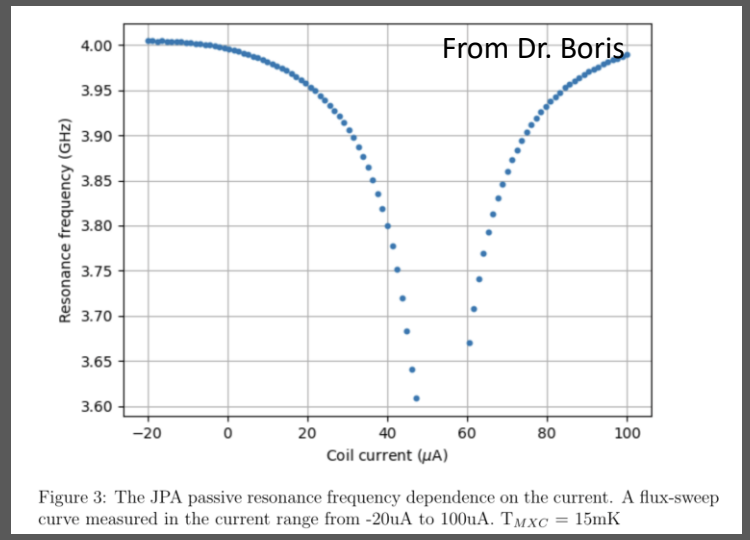


Figure 3: The JPA passive resonance frequency dependence on the current. A flux-sweep curve measured in the current range from -20uA to 100uA. T_{MXC} = 15mK

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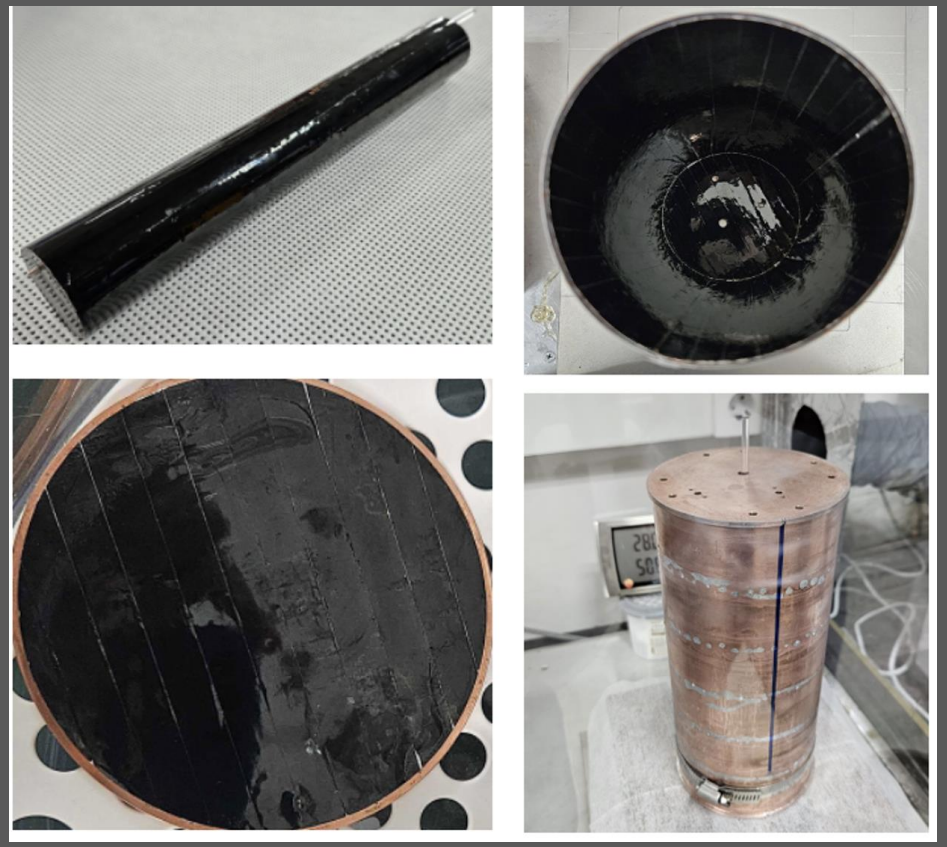
DMAG-8T-4GHz experiment

- **3.6-4GHz** axion search using HTS cavity.
- Flux-driven JPA from RIKEN (Int'l collaboration w/ Nakamura's group)

3.6-4GHz HTS Cavity



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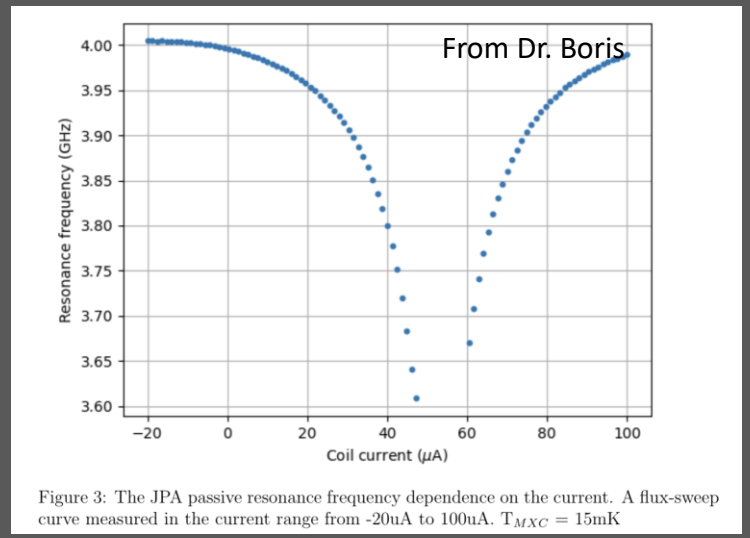

Figure 3: The JPA passive resonance frequency dependence on the current. A flux-sweep curve measured in the current range from -20uA to 100uA. $T_{MXC} = 15$mK

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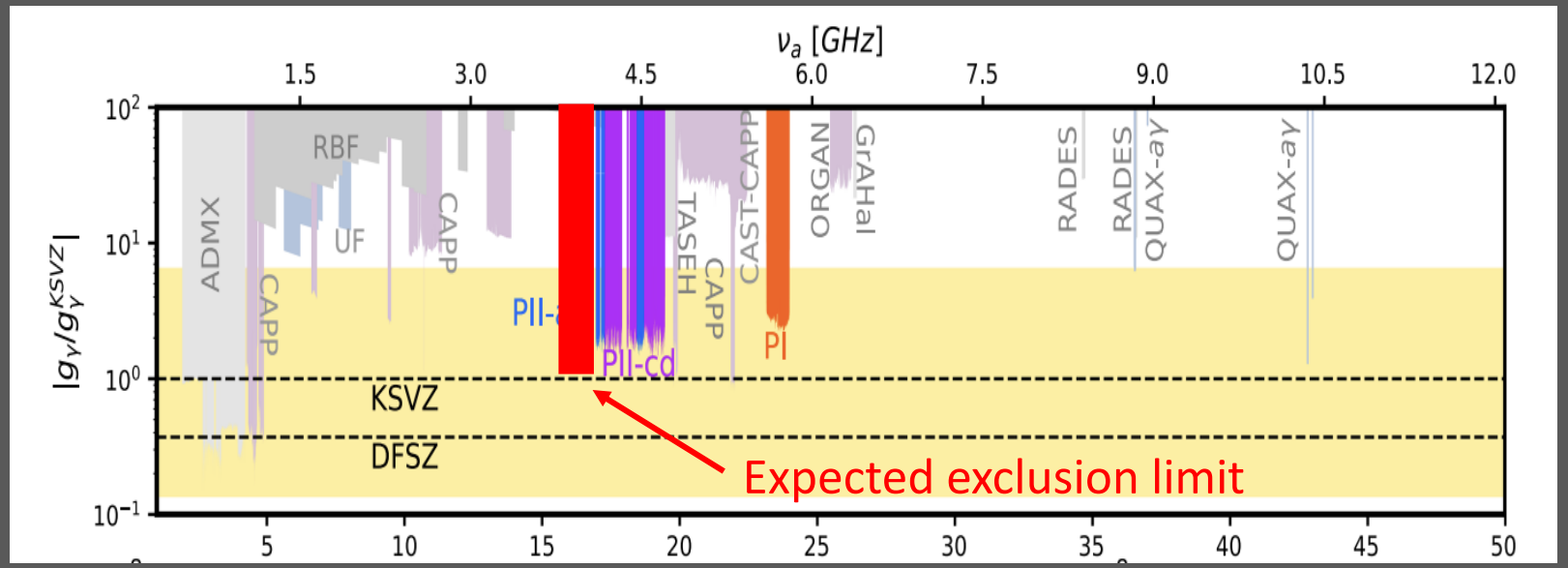
DMAG-8T-4GHz experiment

- Physics run will be performed from November 2025

Experimental parameter of our setup

Parameter	Value
B_ave (T)	7
Cavity volume (L)	1.6
Loaded Q-factor	??
Coupling strength	1.5-2.5
Frequency (GHz)	3.7-4 GHz
Form factor	0.5
System noise (T)	0.3?



KSVZ axion scan rate:

~1MHz/day

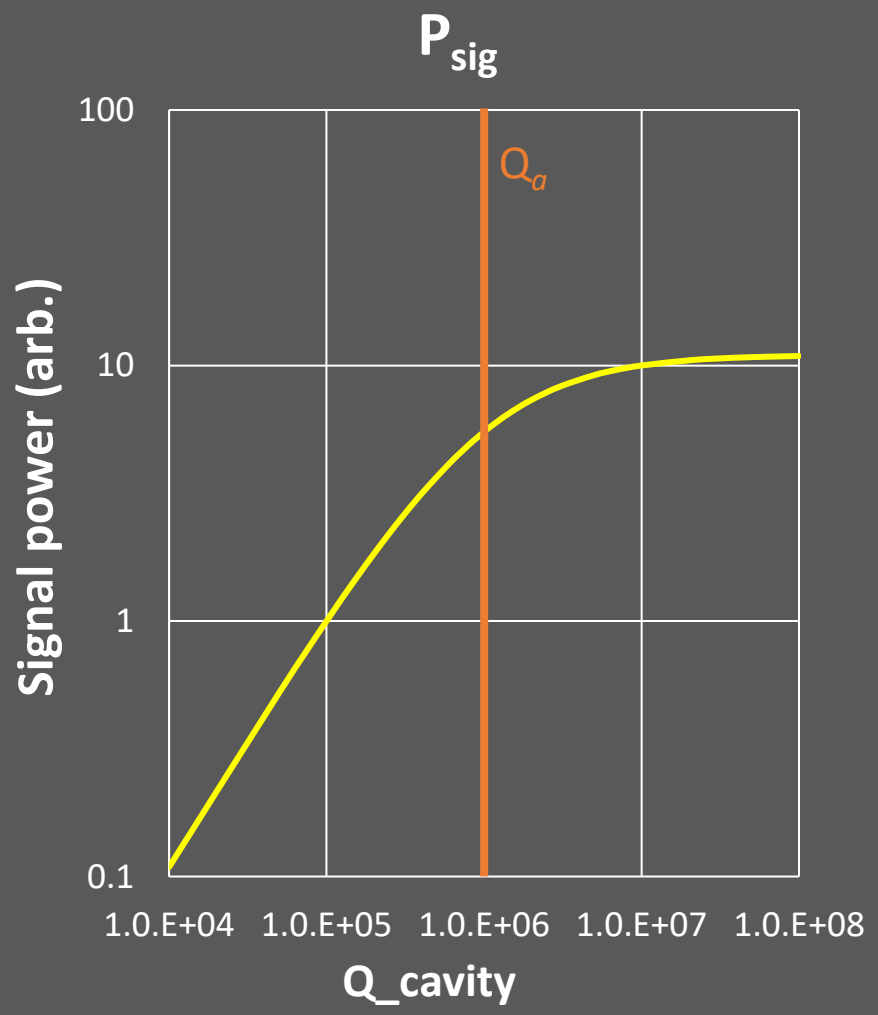
Summary

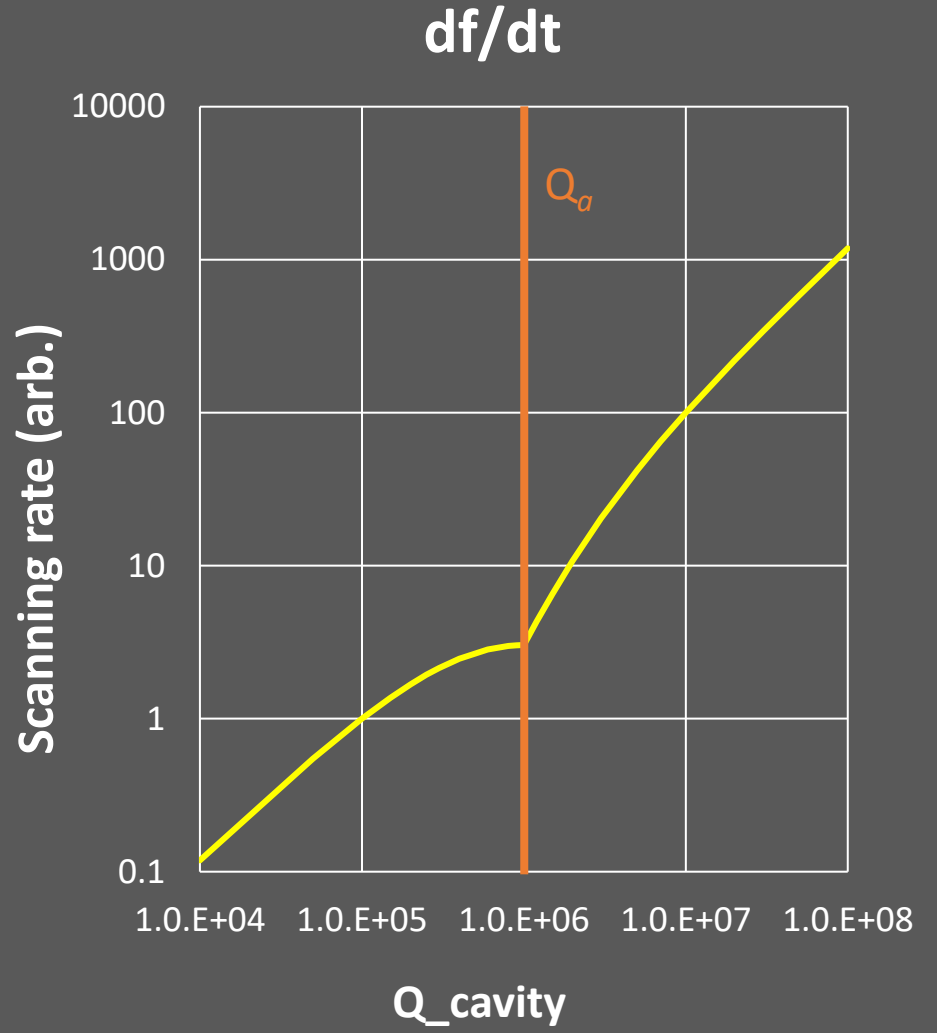
- A high-temperature superconducting (HTS) cavity was successfully integrated into the DMAG-8T setup, which features an 8 T magnet and a dilution refrigerator.
- The 5.4 GHz HTS cavity achieved a record-high $Q > 3.5 \times 10^6$ with $T_{sys} \approx 0.4$ K, demonstrating field-induced frequency via HTS magnetization without using a mechanical tuning rod.
- Axion search data were collected in June 2025 using a flux-driven JPA, and analysis is ongoing.
- A new $3.7 - 4$ GHz HTS cavity system is being prepared, with the next physics run planned for November 2025.

Backup slides

High-Q boosts axion scanning speed

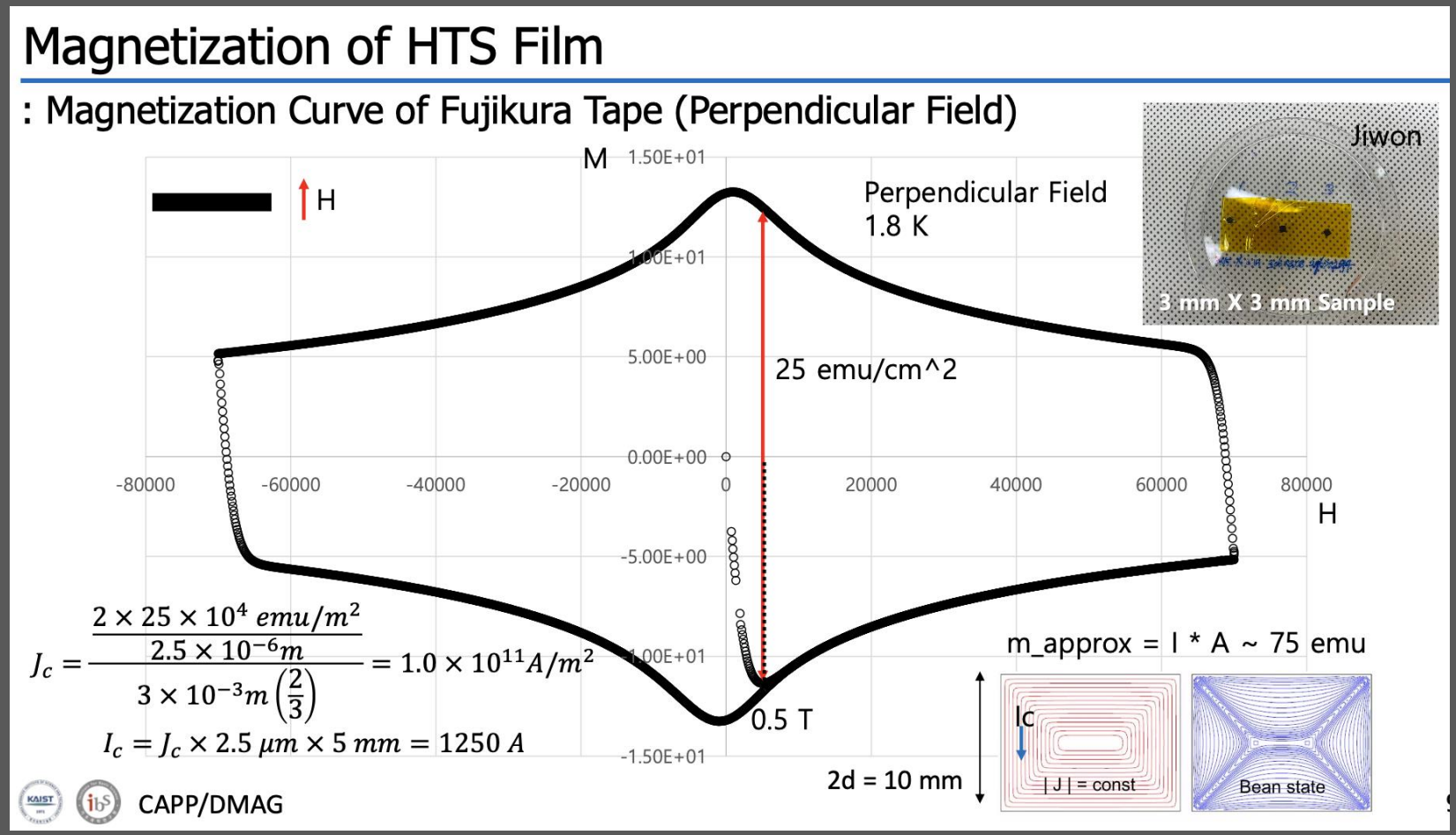
D. Kim et al., Physics A *(2020), 03* R. Cervantes et al., Phys. Rev. D 110, 043022





DMAG-8T-5.4GHz experiment

- ***Frequency tuning using HTS magnetization***



From Dr. Danho Ahn's slides

In strong B-field,

Enormous current flows on HTS surface while ramping up or down

Strong force the cavity surface

$$F = BiL$$

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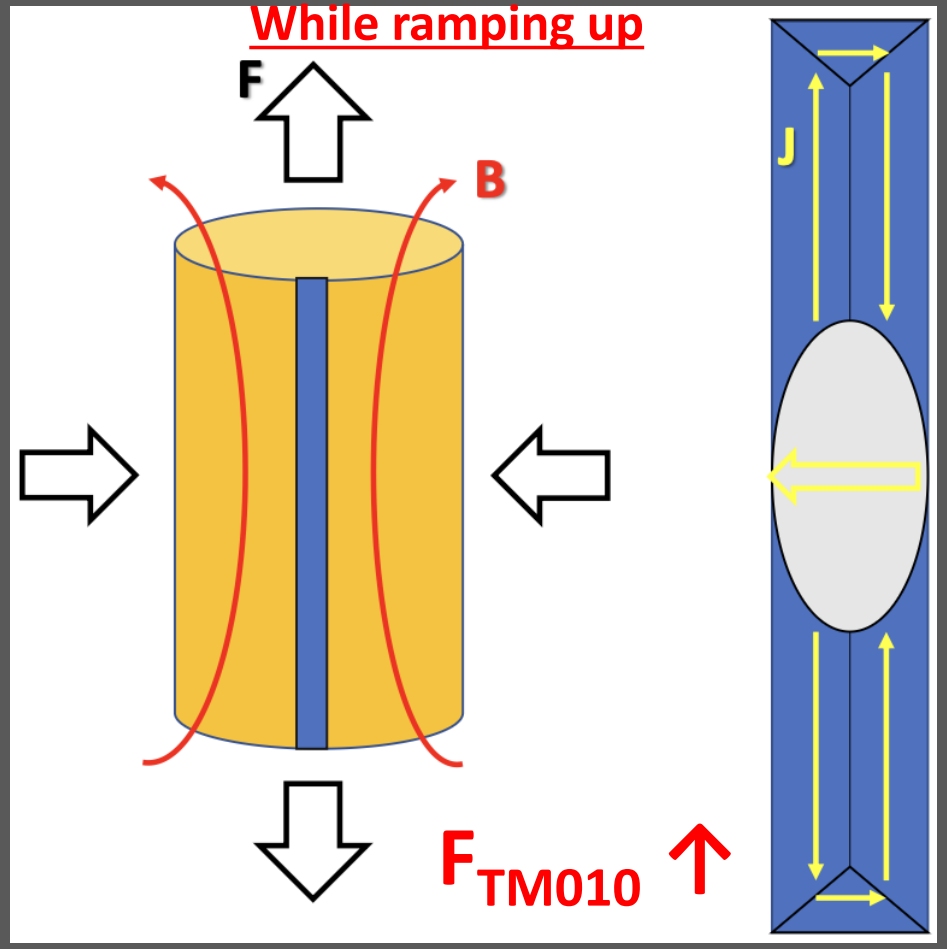
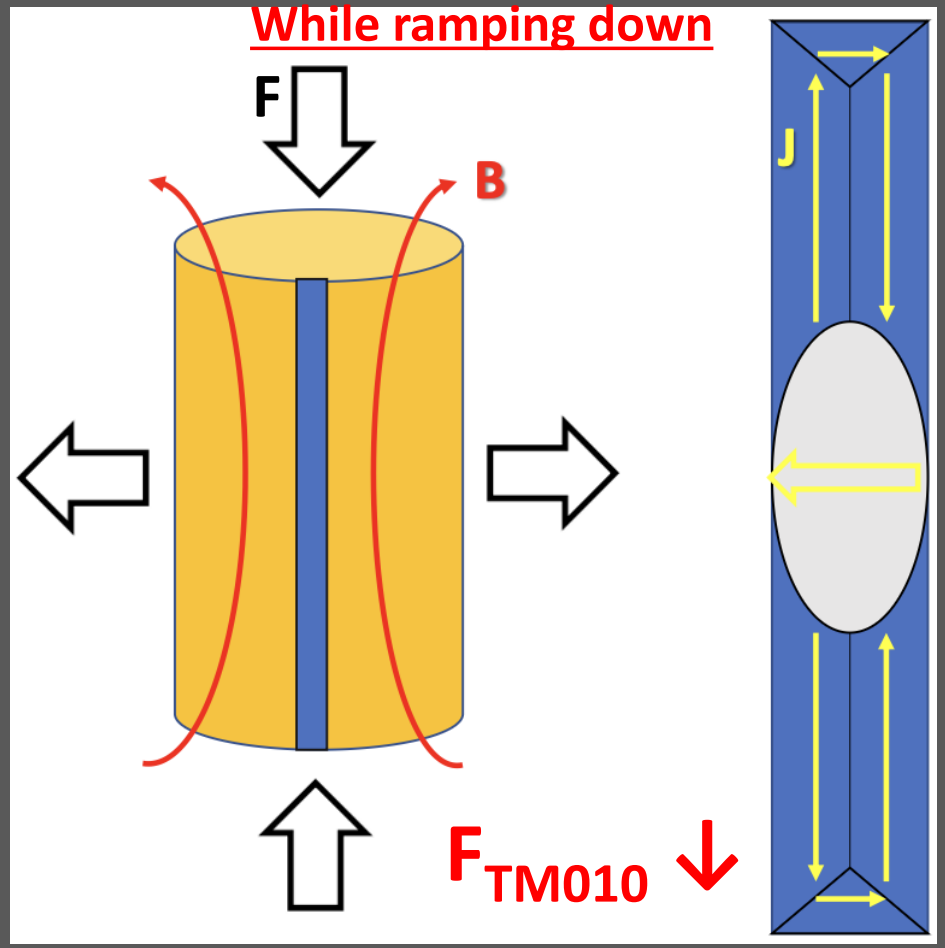
DMAG-8T-5.4GHz experiment

- ***Frequency tuning using HTS magnetization***





From Dr. Danho Ahn's slides

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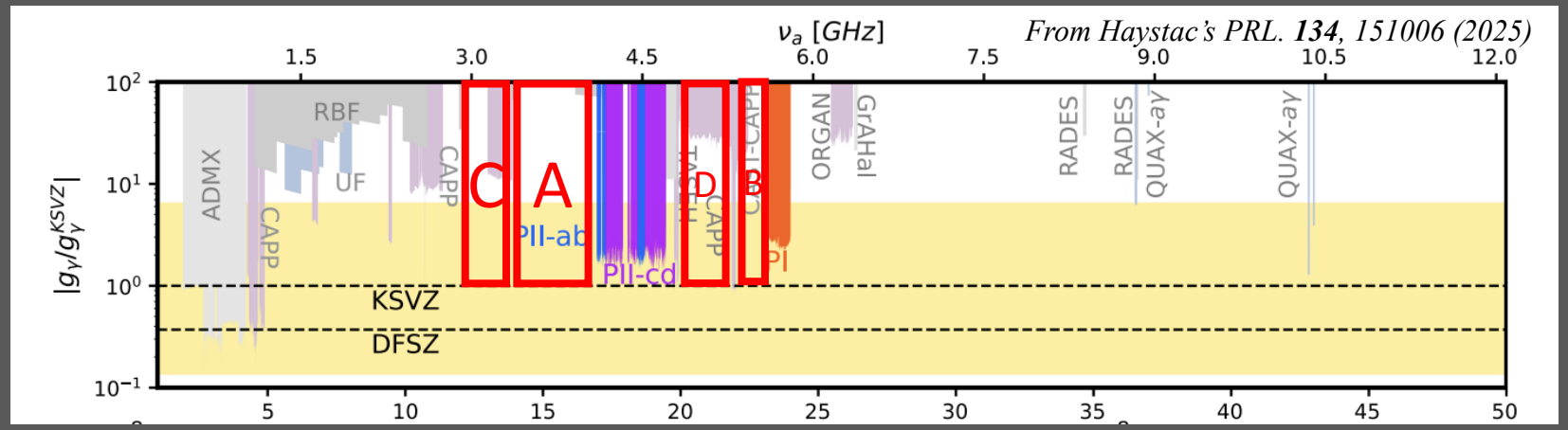
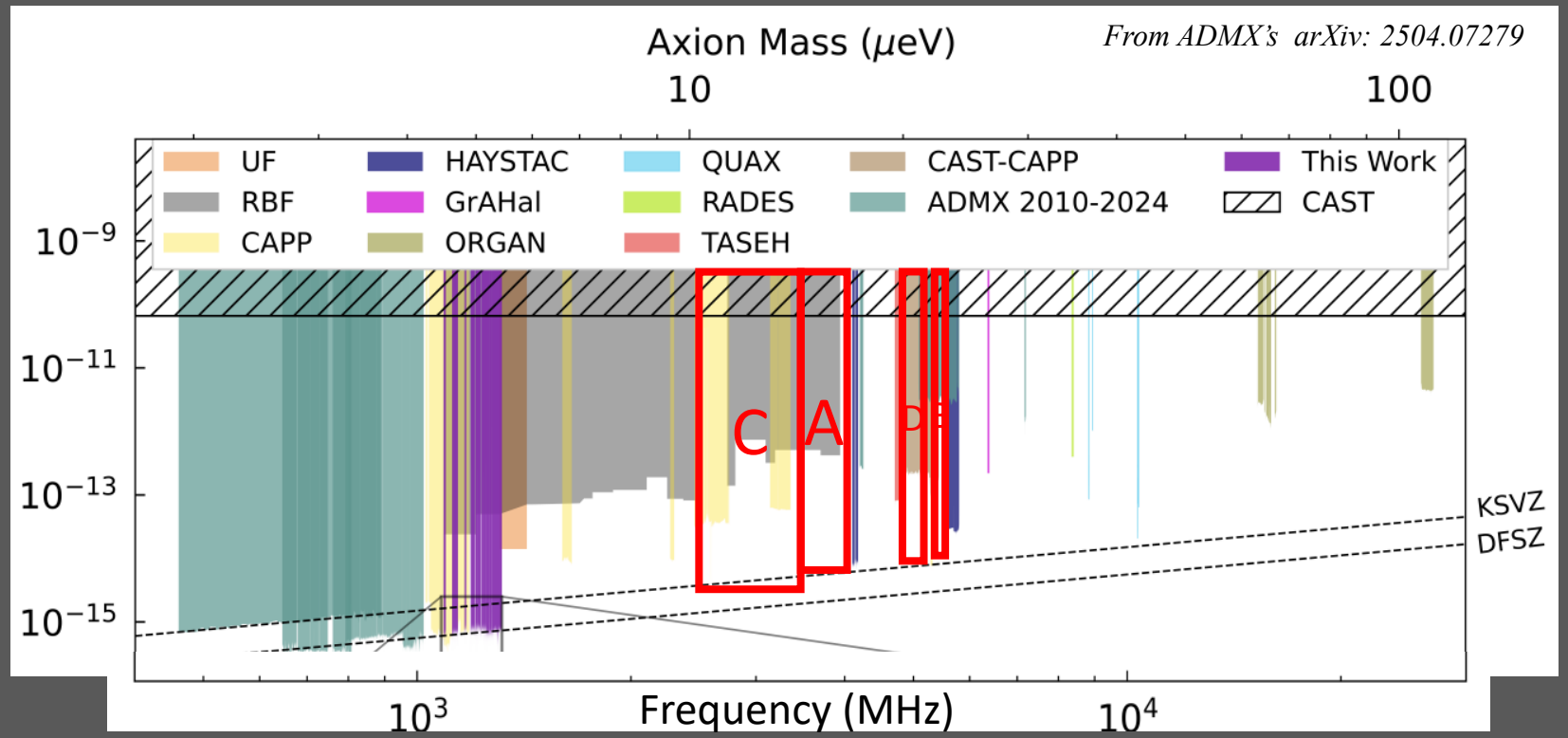

From Haystac's PRL. 134, 151006 (2025)
ν_a [GHz]
$|g_\gamma/g_\gamma^{KSVZ}|$
ADMX
RBF
UF
CAPP
C
A
PII-ab
PII-cd
D
B
ORGAN
GrAHal
RADES
QUAX-aγ
KSVZ
DFSZ


From ADMX's arXiv: 2504.07279
Axion Mass (μeV)
UF
RBF
CAPP
HAYSTAC
GrAHal
ORGAN
QUAX
RADES
TASEH
CAST-CAPP
ADMX 2010-2024
This Work
CAST
C
A
KSVZ
DFSZ
Frequency (MHz)

JPAs?