The ALPHA axion dark matter experiment

Andrea GALLO ROSSO

Stockholm University

alpha SIMONS FOUNDATION
JOHN TEMPLETON FOUNDATION
Inspiring Awe & Wonder
OLLE ENGKVISTS STIFTELSE
Swedish Research Council
Knut och Alice Wallenbergs Stiftelse

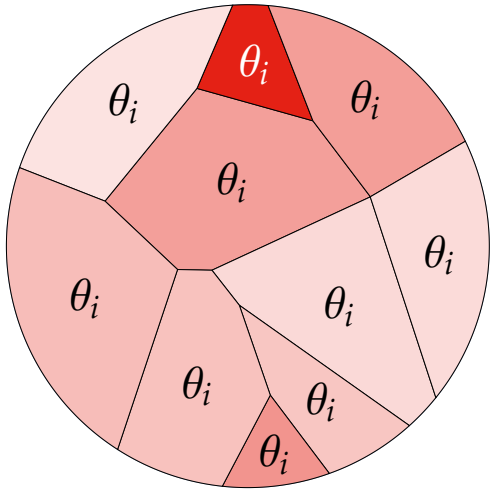
SETTING

Inflation

↓

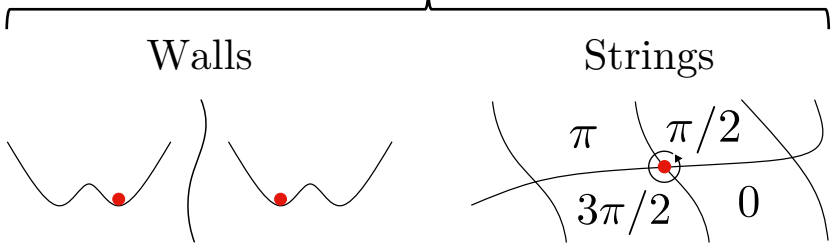
PQ-symmetry breaking

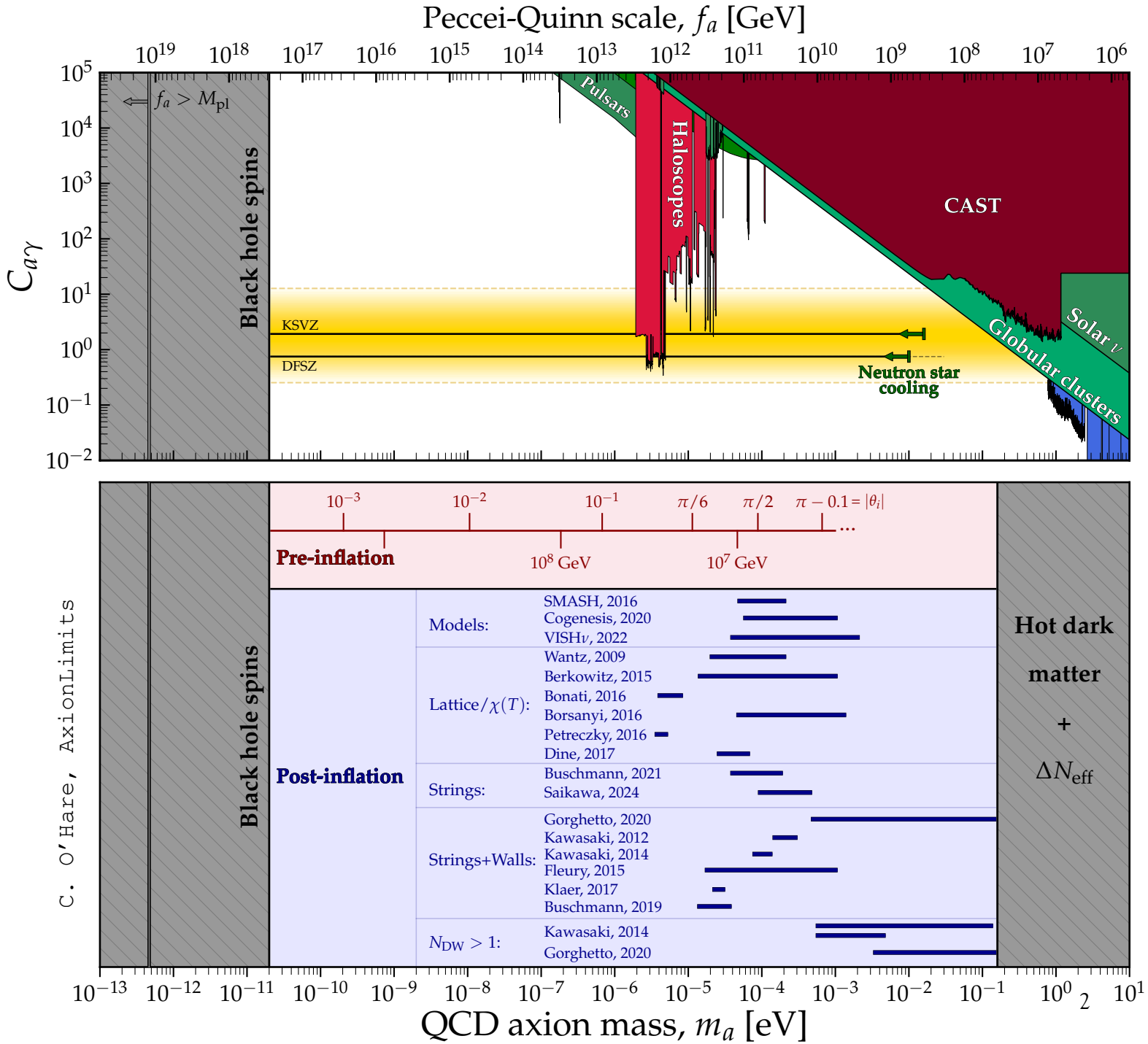
$\theta(\vec{x}, t) = A(\vec{x}, t)/f_A$



↓

Decay of topological defects





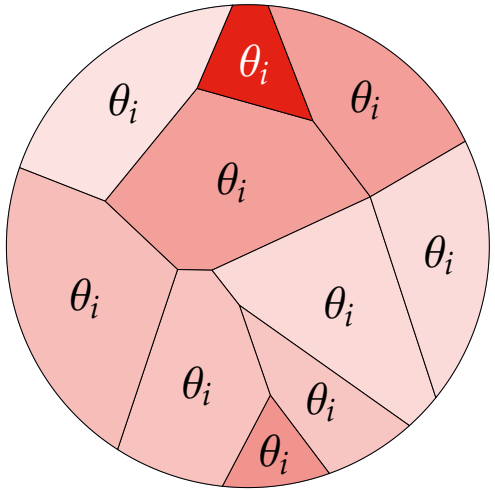
SETTING

Inflation

↓

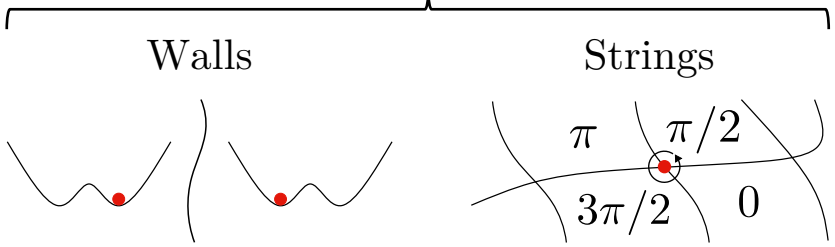
PQ-symmetry breaking

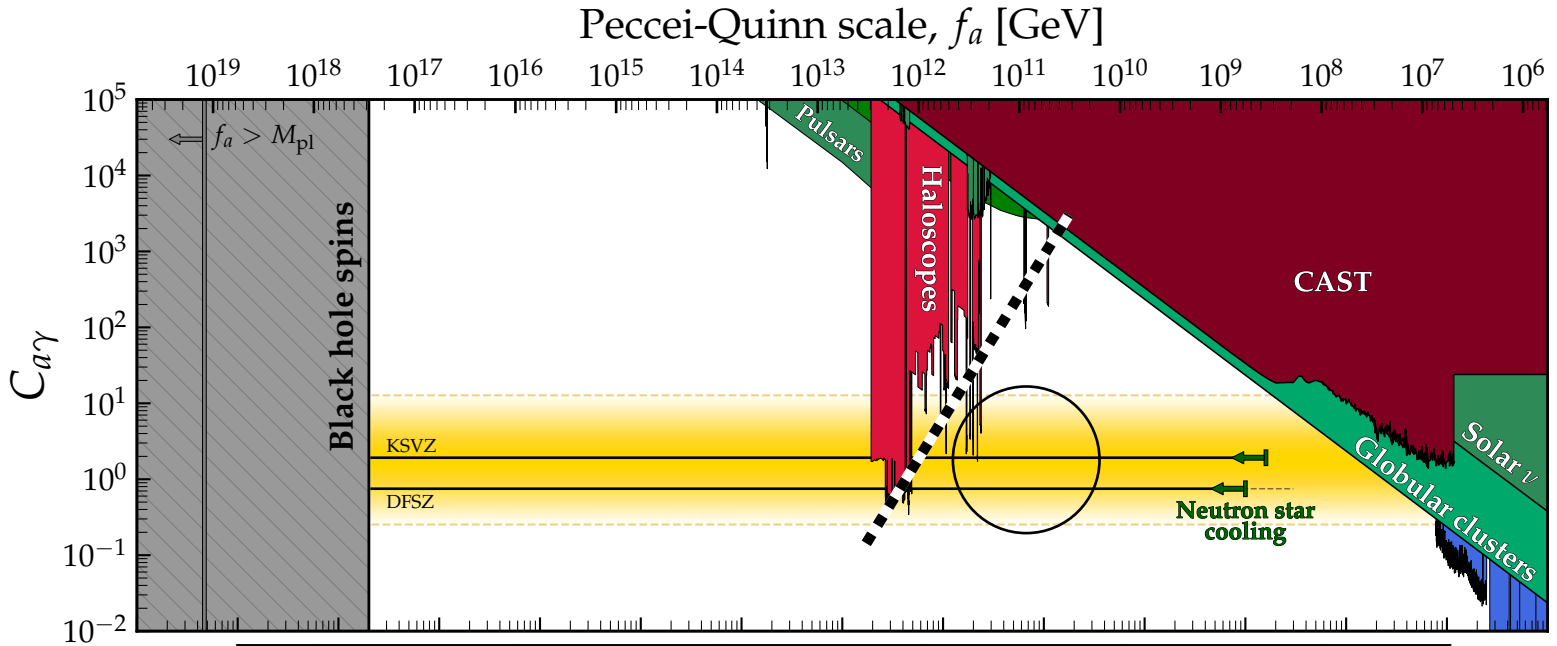
$\theta(\vec{x}, t) = A(\vec{x}, t)/f_A$

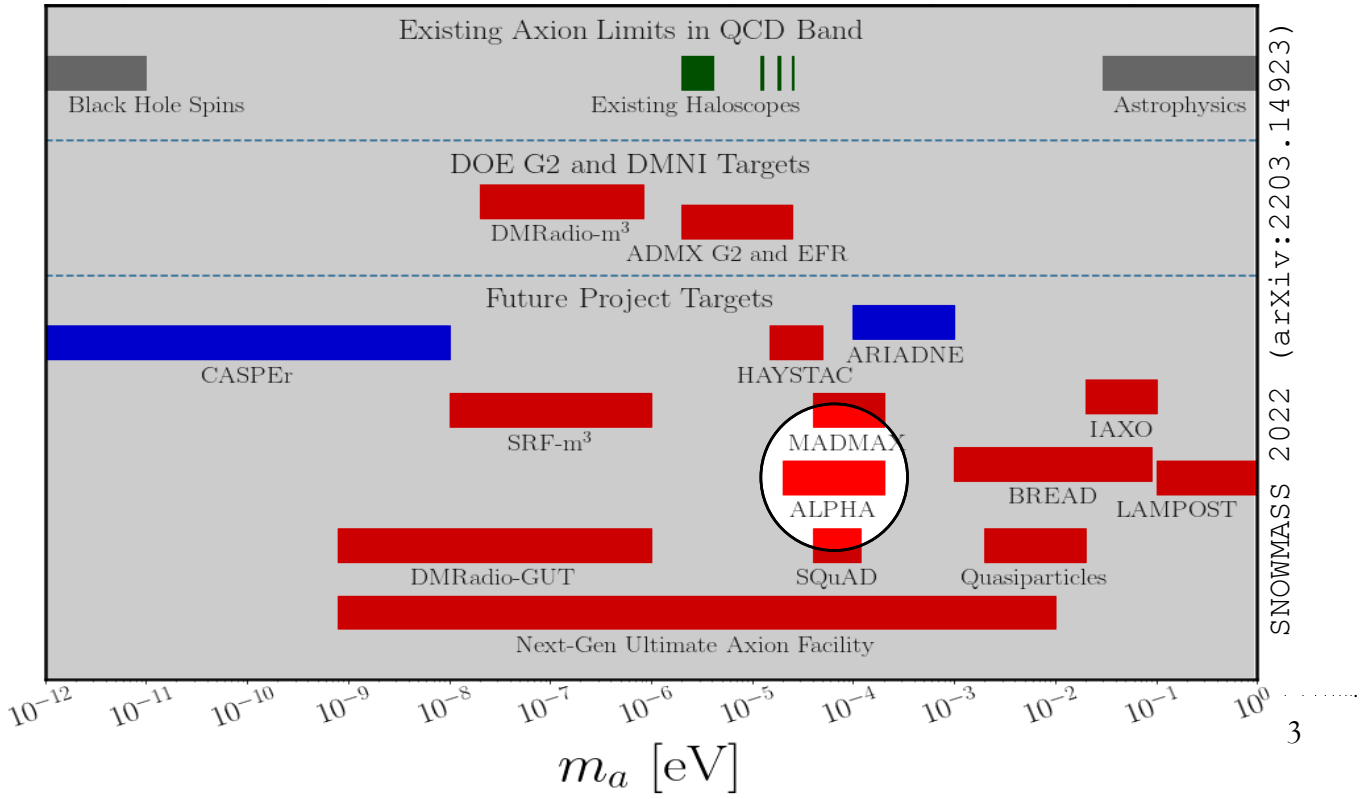


↓

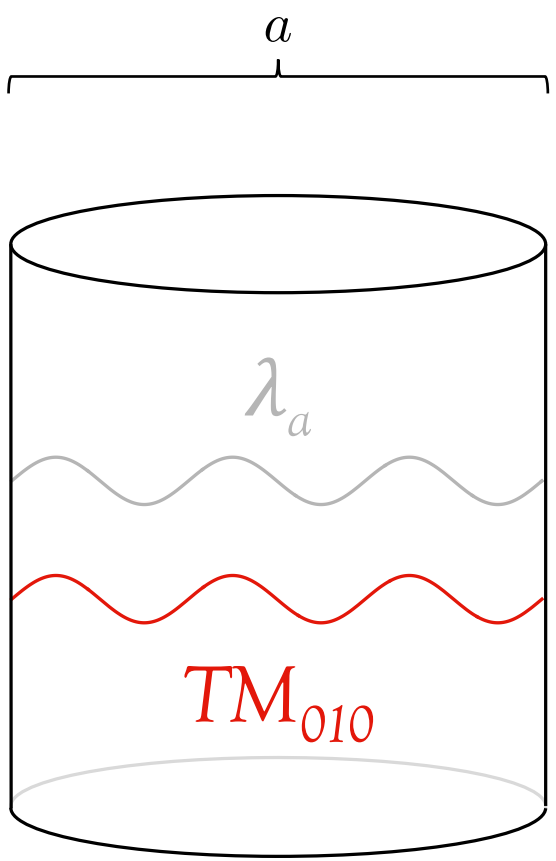
Decay of topological defects







PLASMONIC RESONANCE



ME

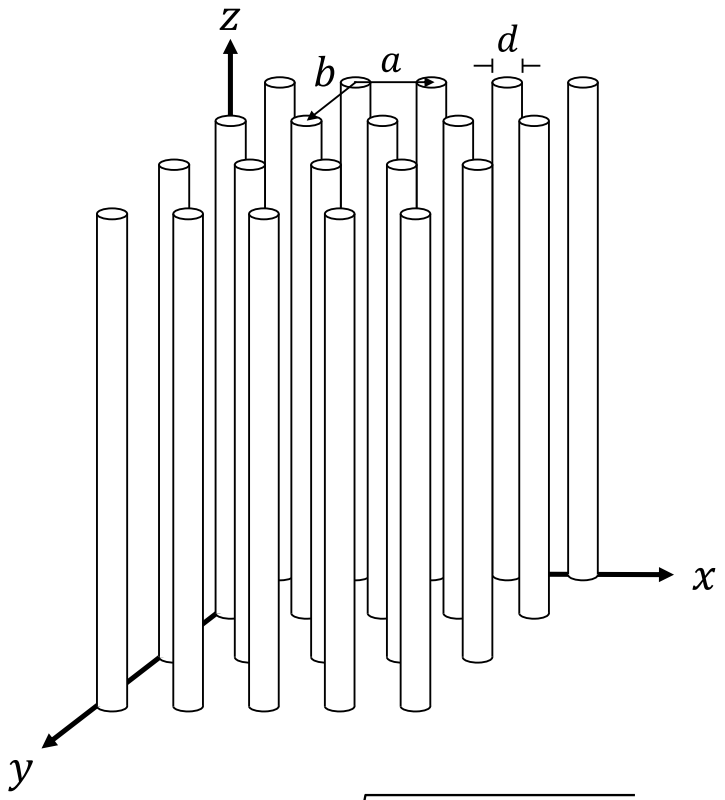
Co s with different

pro r single parts.

$$\nu_{res} = \frac{1.202}{\pi}\frac{c}{a}$$

Sikivie, Phys. Rev. Lett. 51, 1415 (1983)

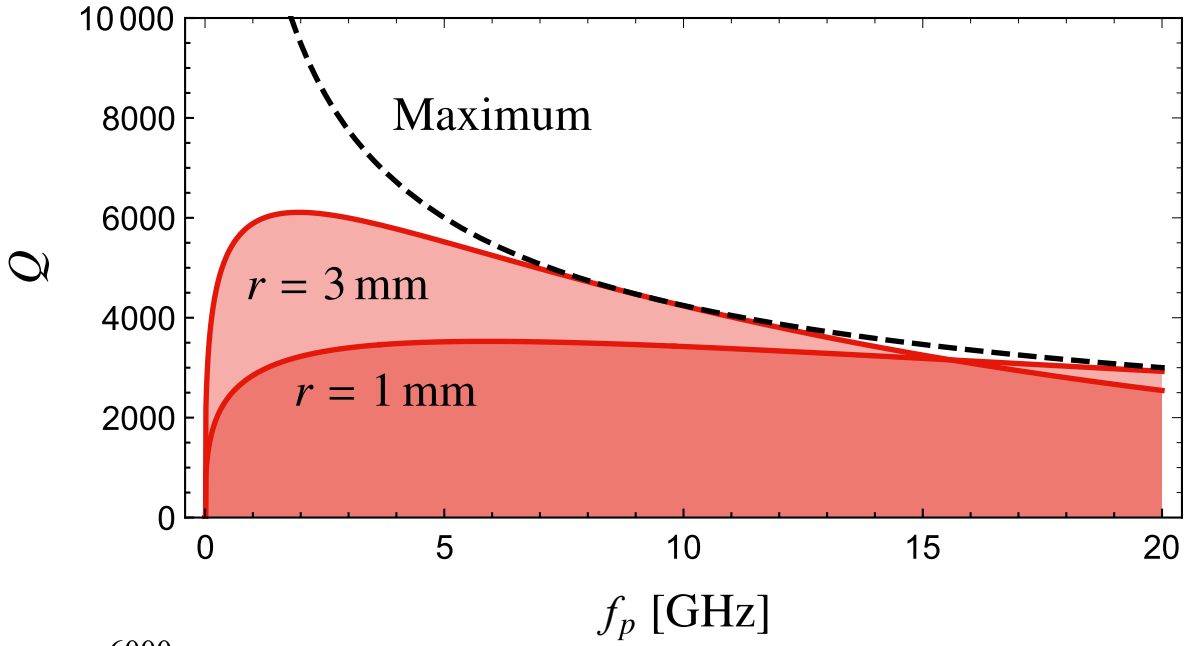
$$a \sim 1\,\text{cm} \iff \nu_{res} \sim 10\,\text{GHz}$$

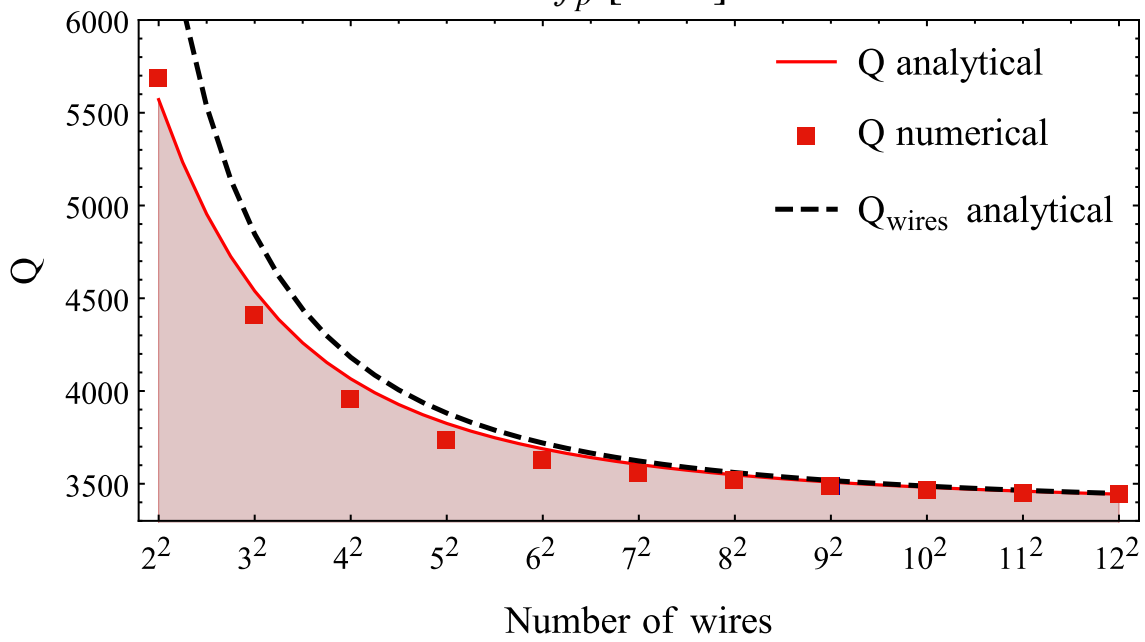


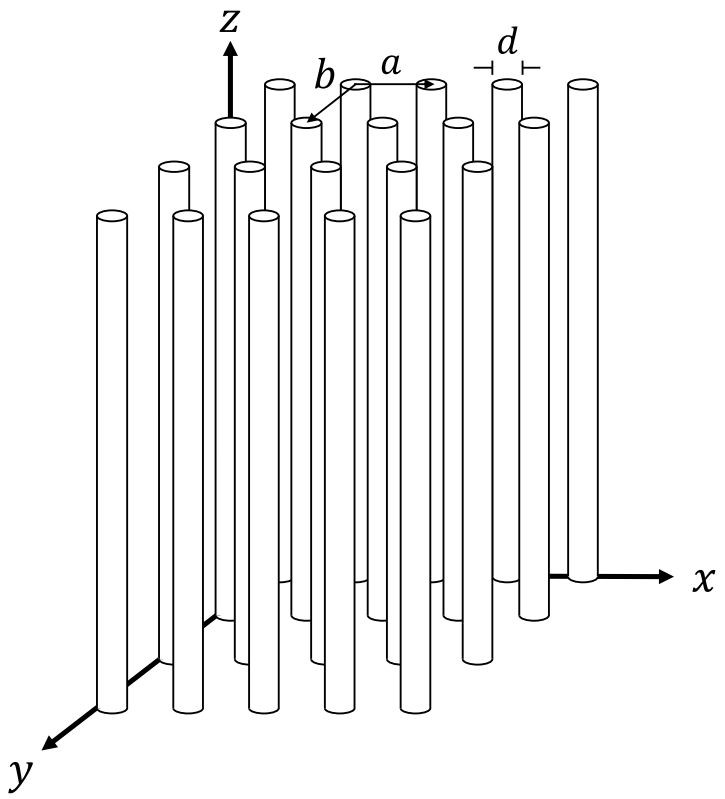
$$\nu_{res} = \frac{c}{a}\sqrt{\frac{1}{2\pi \ln(a/r)}}$$

Belov et al., JEWA 16, 1153-1170 (2002)
Lawson et al., Phys. Rev. Lett. 123, 141802 (2019)

TUNING R&D

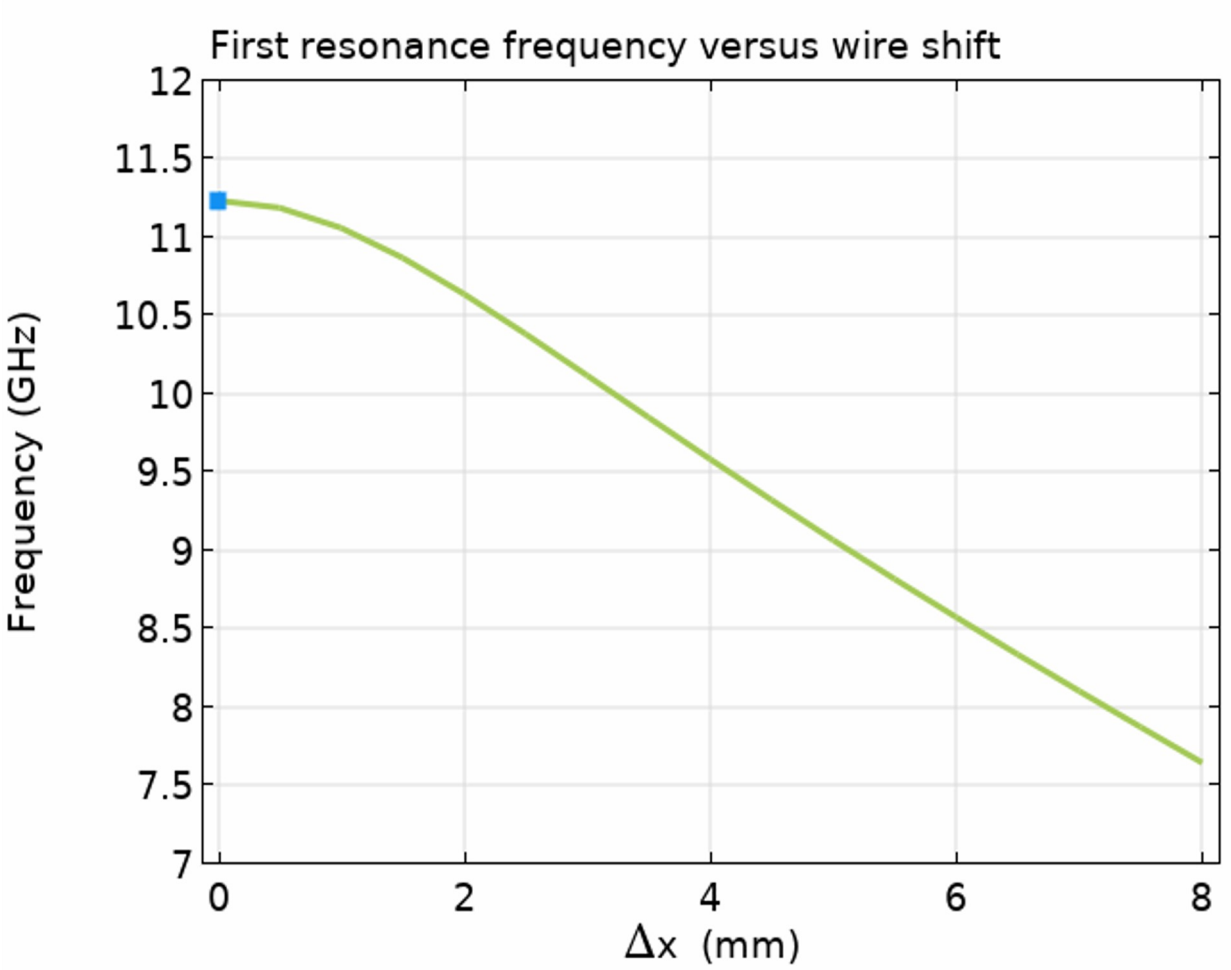


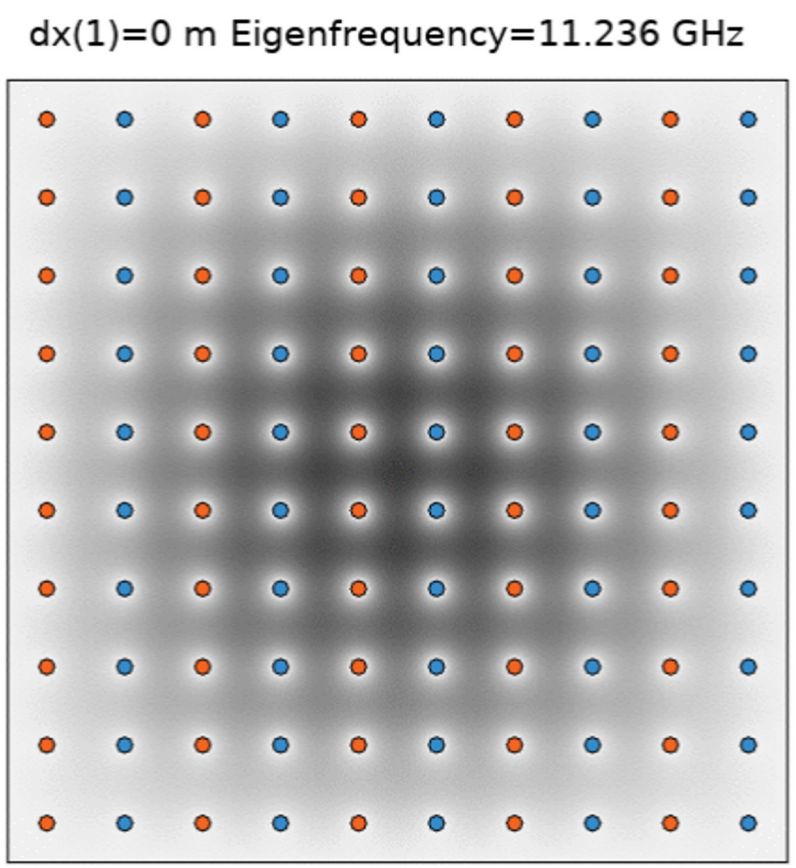




Belov et al., Phys.Rev.B 106 7, 075106 (2022)

TUNING



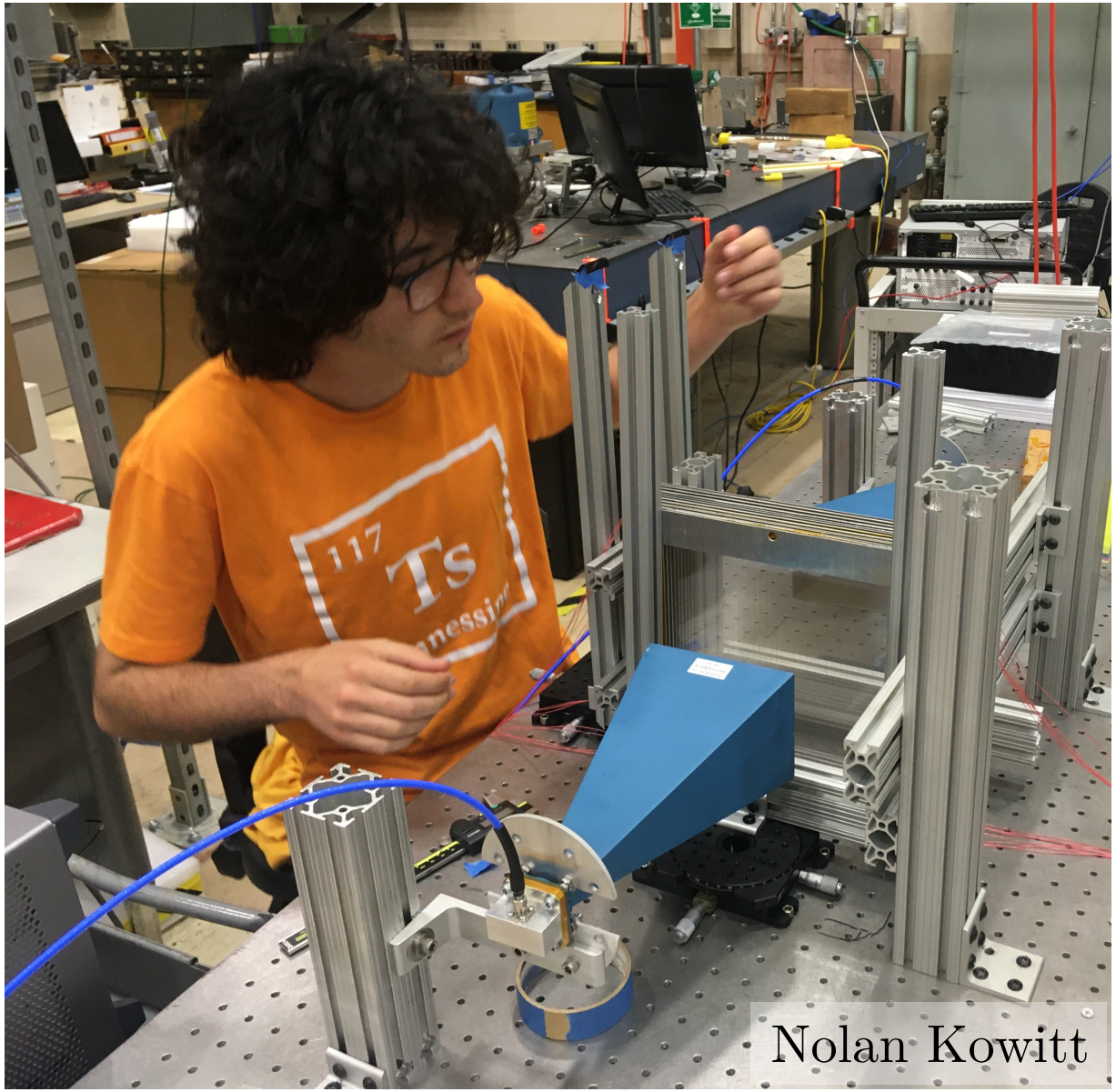


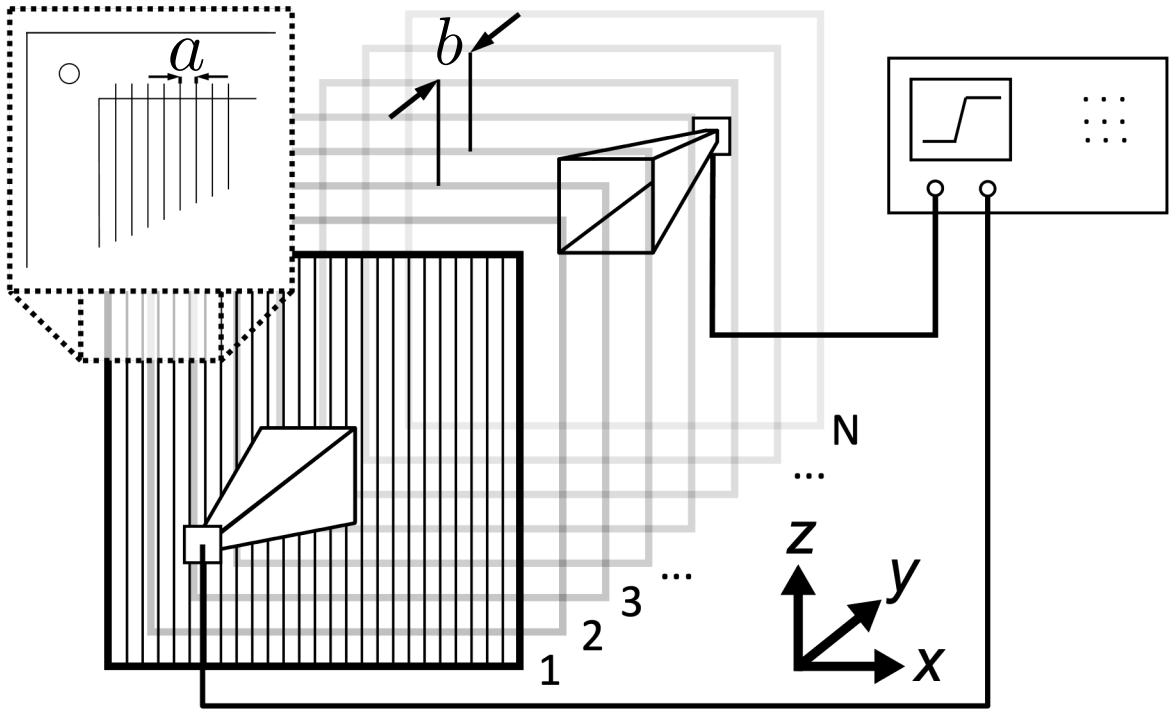
Millar et al., PRD 107, 055013 (2022)
Balafendiev at al. PRB 106, 075106 (2022)

Lateral translation

Theoretically feasible but nontrivial implementation in closed cavities

UC BERKELEY

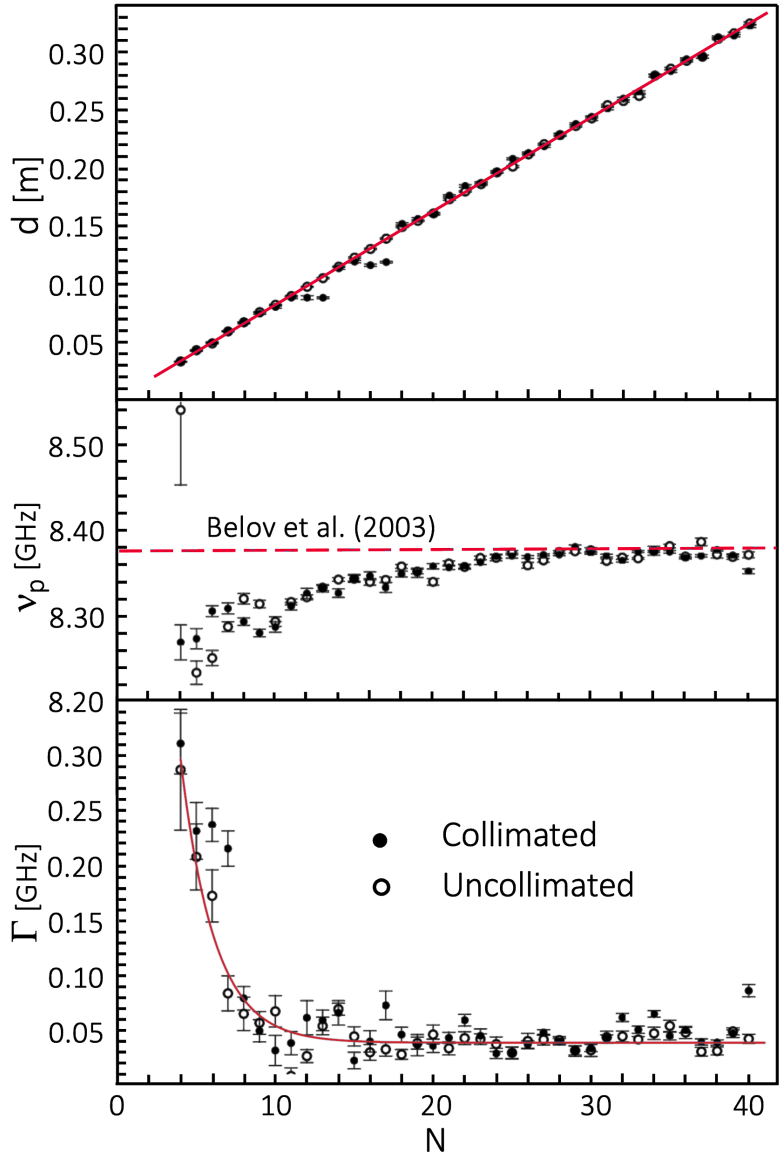




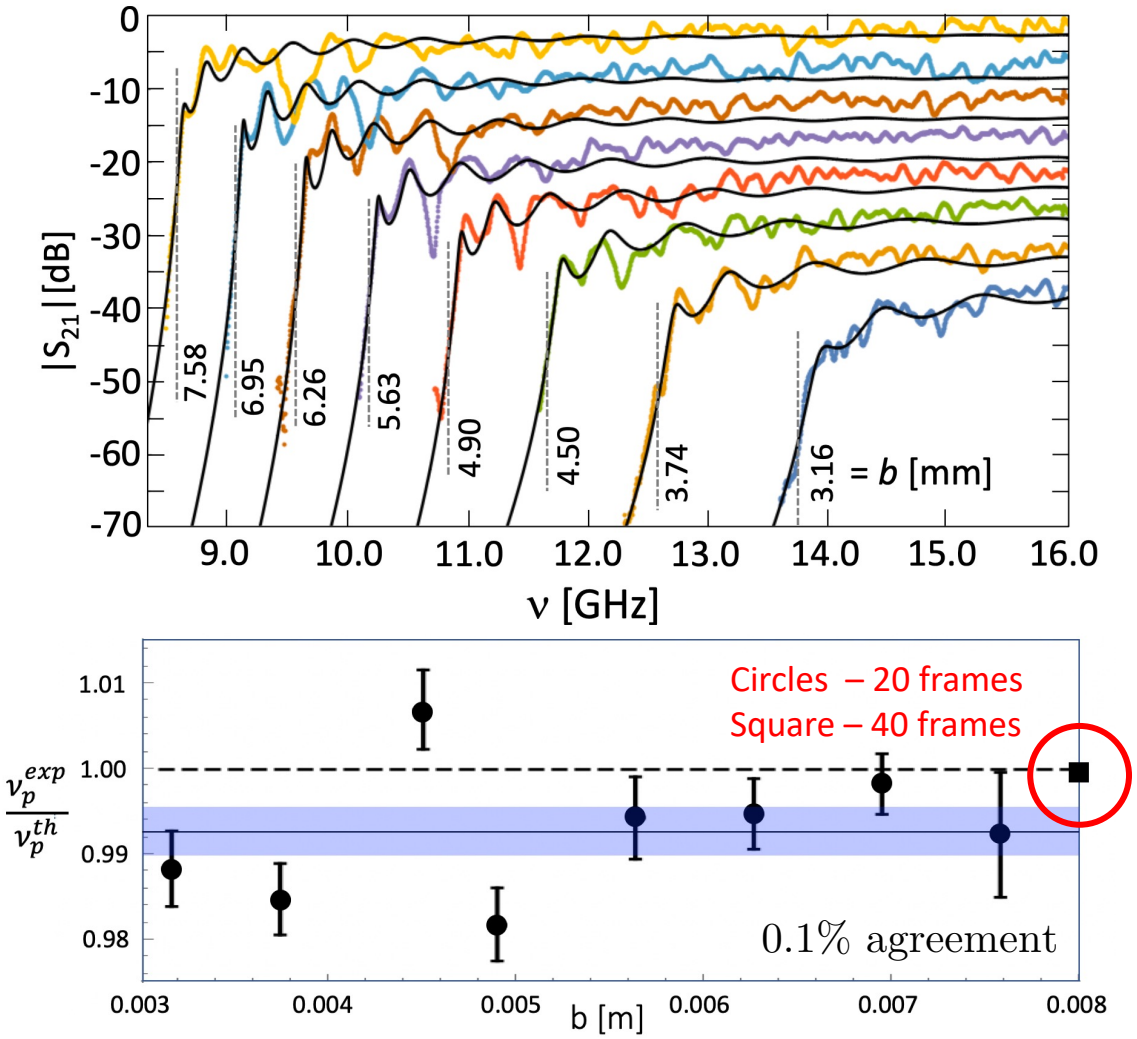
UC BERKELEY

$$Q = \nu_p / G > 10^4$$

(optimized)
see Balafendiev 2022



Wooten et al. Annalen Phys. 536 (2024)



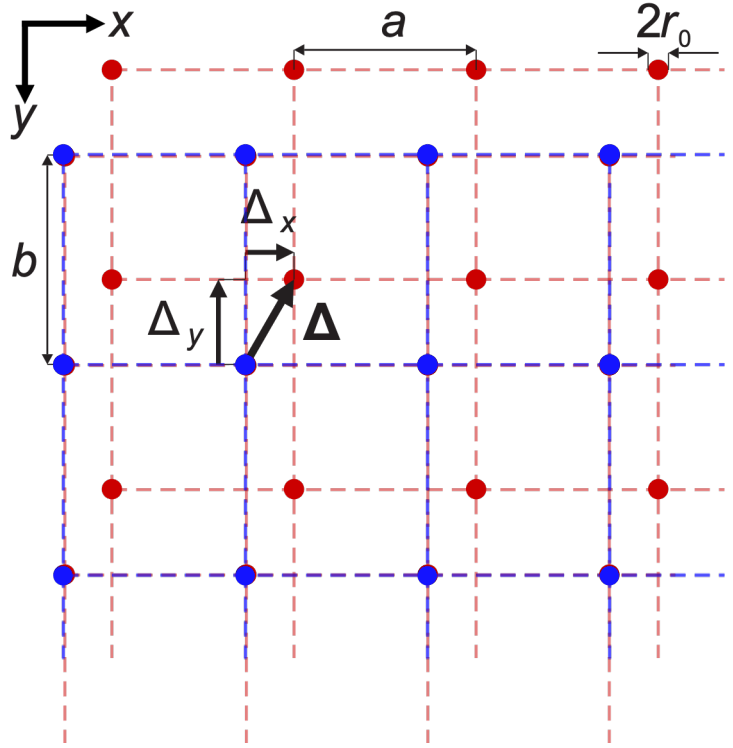
Kowitt et al., Phys.Rev.Applied 20 (2023)

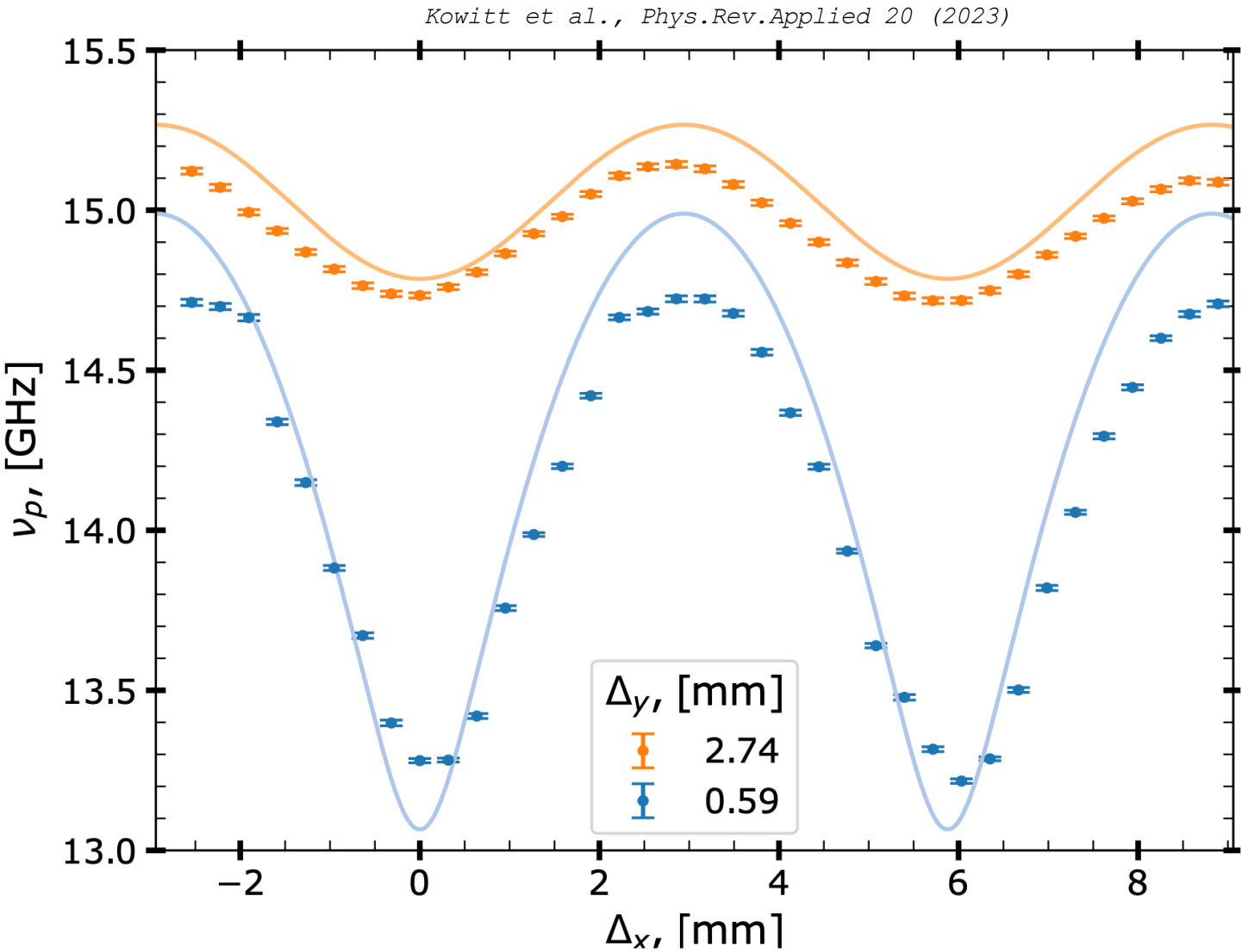
UC BERKELEY: TUNING

From planes to cells

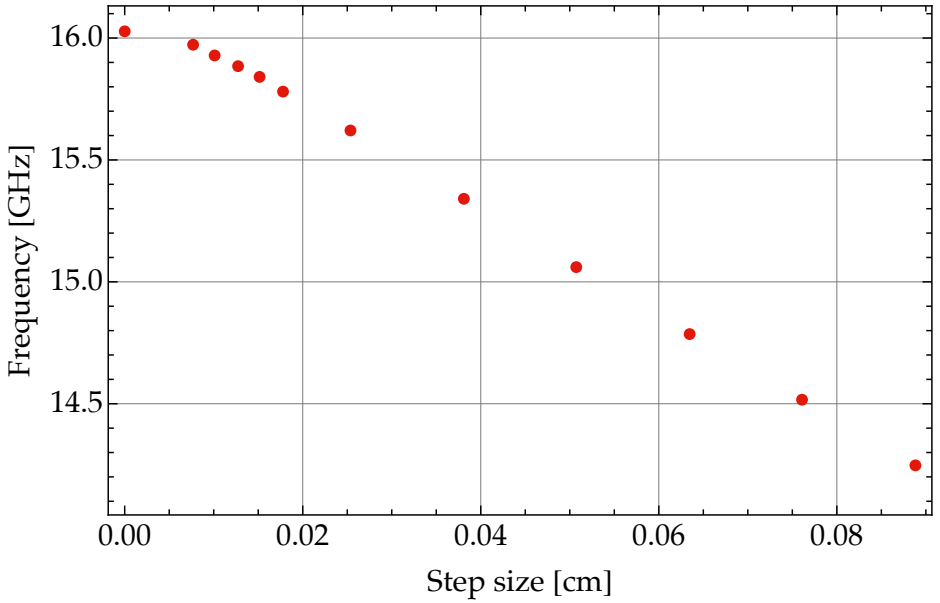
Most practical, volume conserving

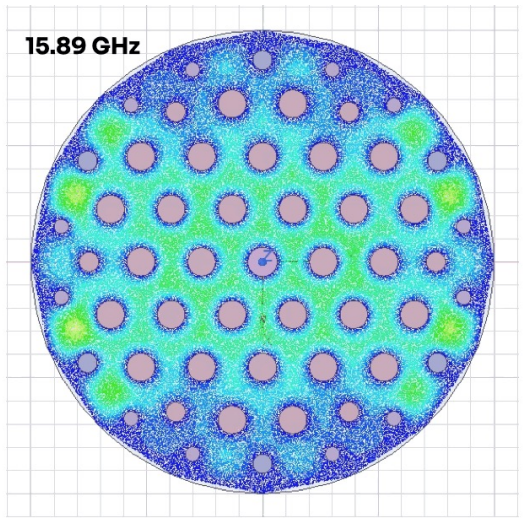
16% dynamic range in frequency



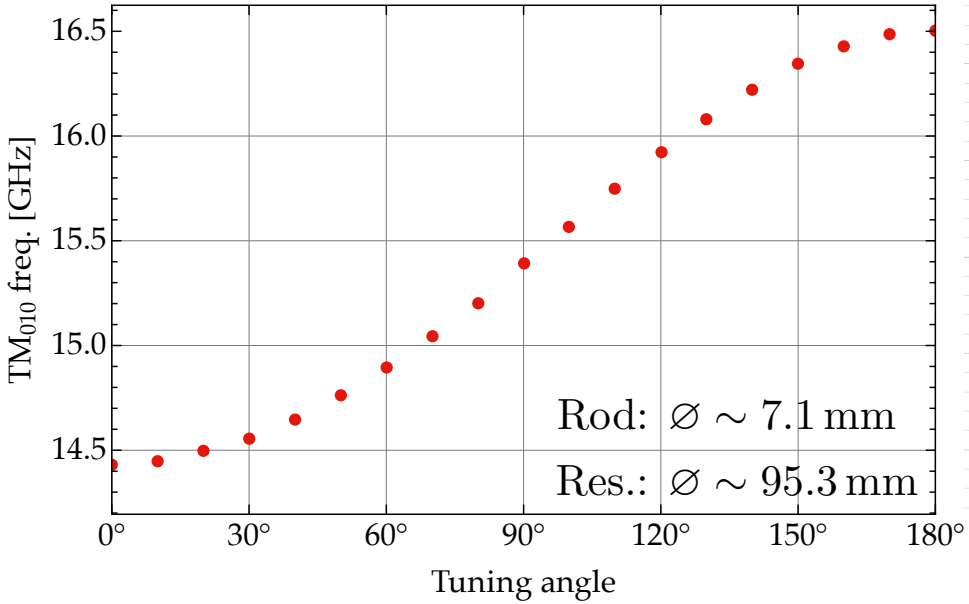


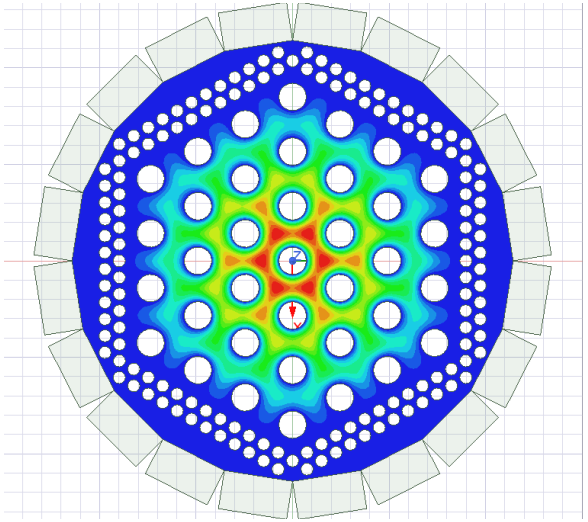
UC BERKELEY: TUNING





55 ROD TRIANGULAR LATTICE
HAYSTACK format
10.2 cm I.D., 25.4 cm long





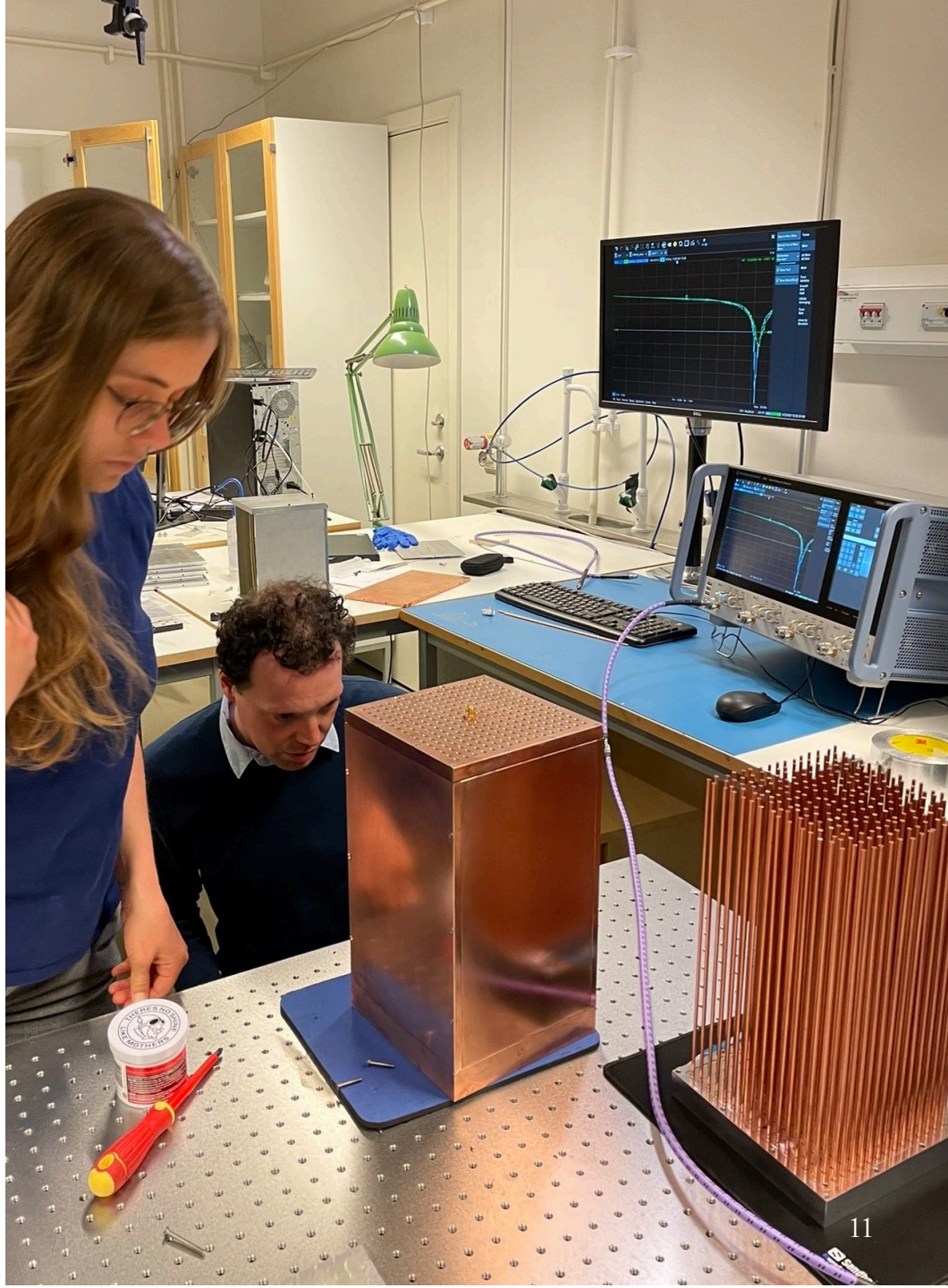
37 ROD TRIANGULAR LATTICE
ALPHA Phase Ia (2024-25)
Tunable lattice
Photonic band gap

STOCKHOLM UNIVERSITY

Starting big

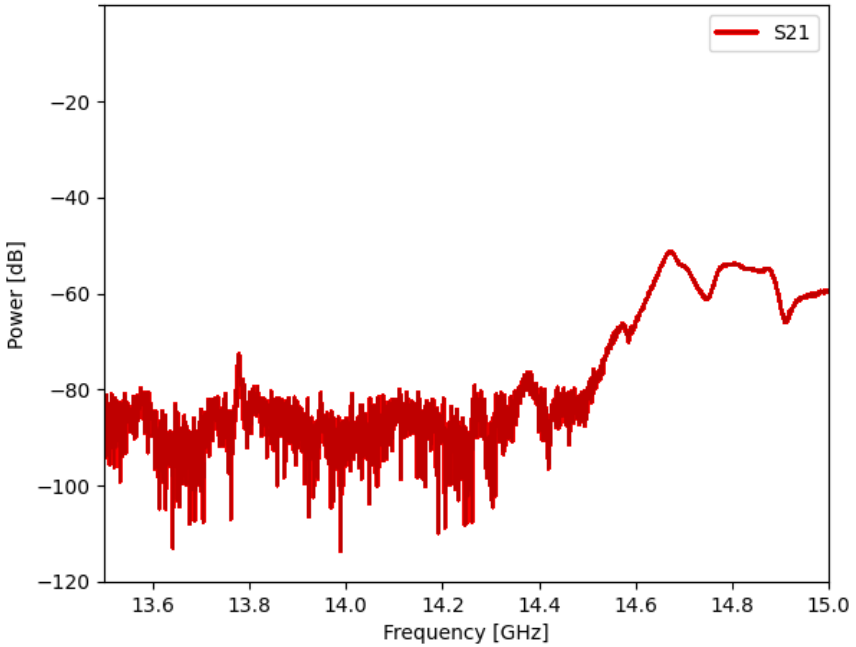
Clear plasmonic resonance

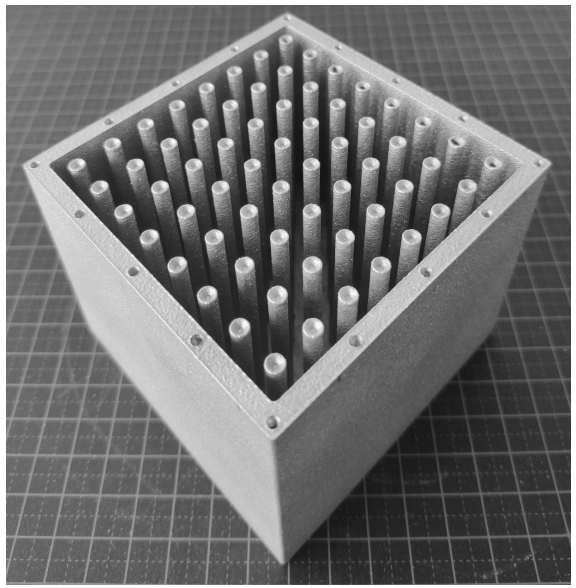
Lossy system

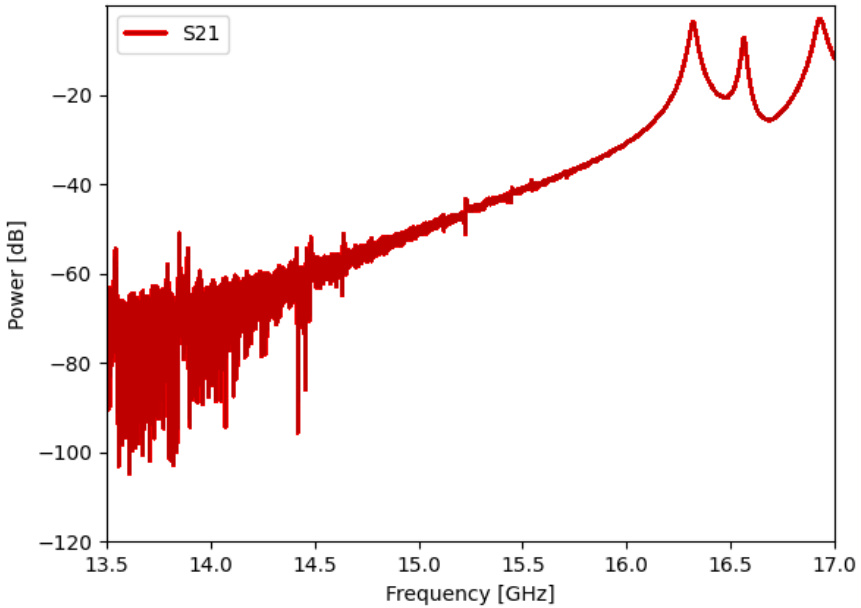


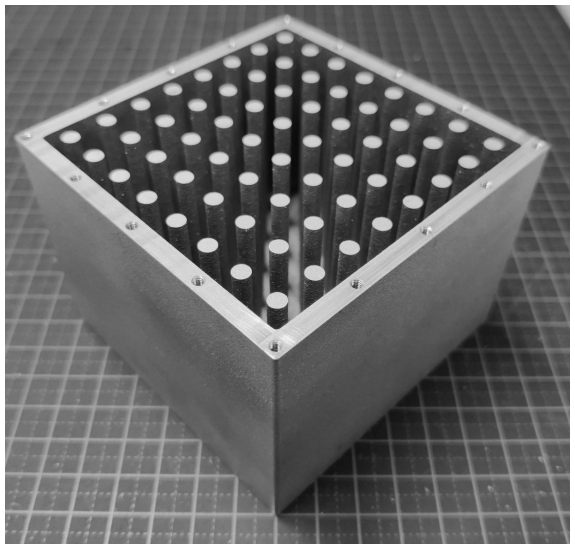
Tove Klaesson and Alexander Millar (2022)

STOCKHOLM UNIVERSITY









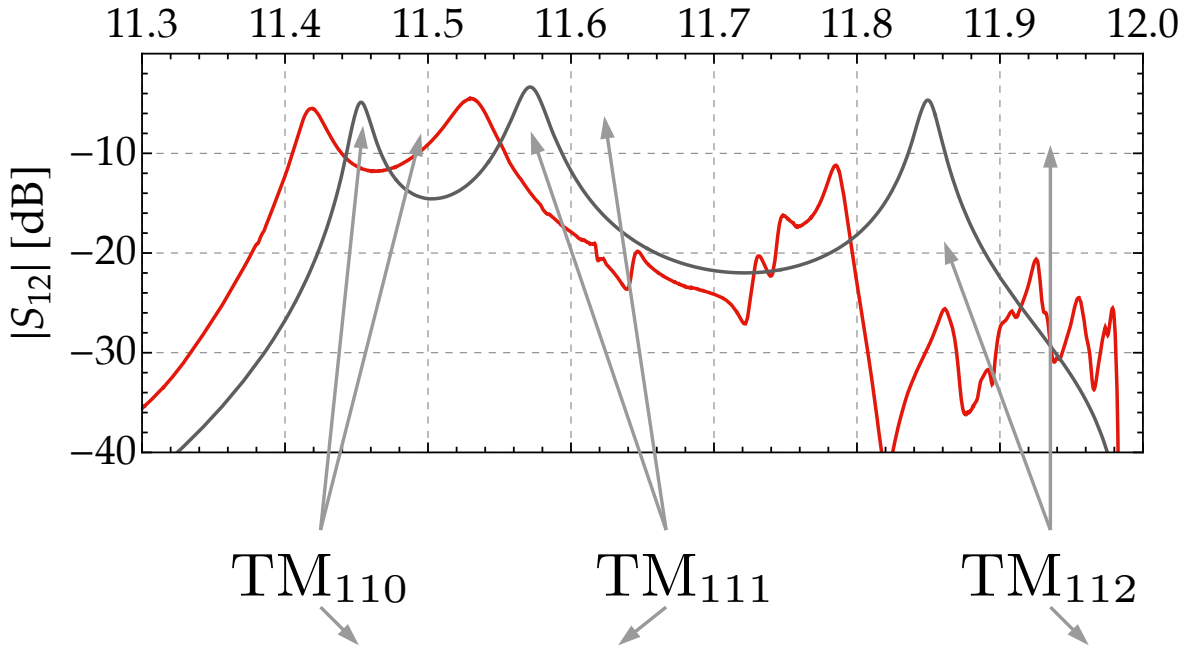
Unibody cavity

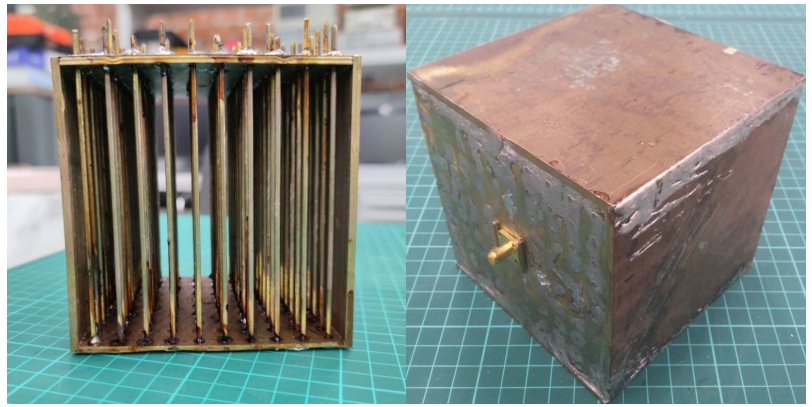
- 3D printed
- Al-Si10Mg powder
- 25-70 μm particles
- DC conductivity 25% of Al

Flat rods

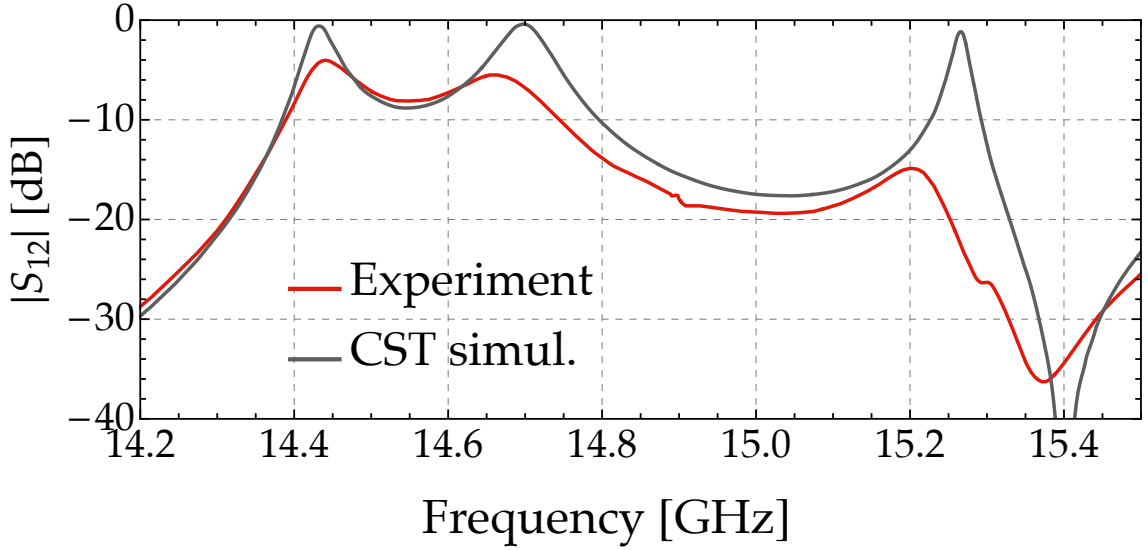
Better connection rods-plate

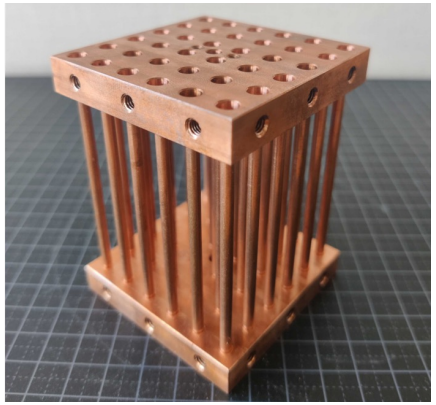
STOCKHOLM UNIVERSITY





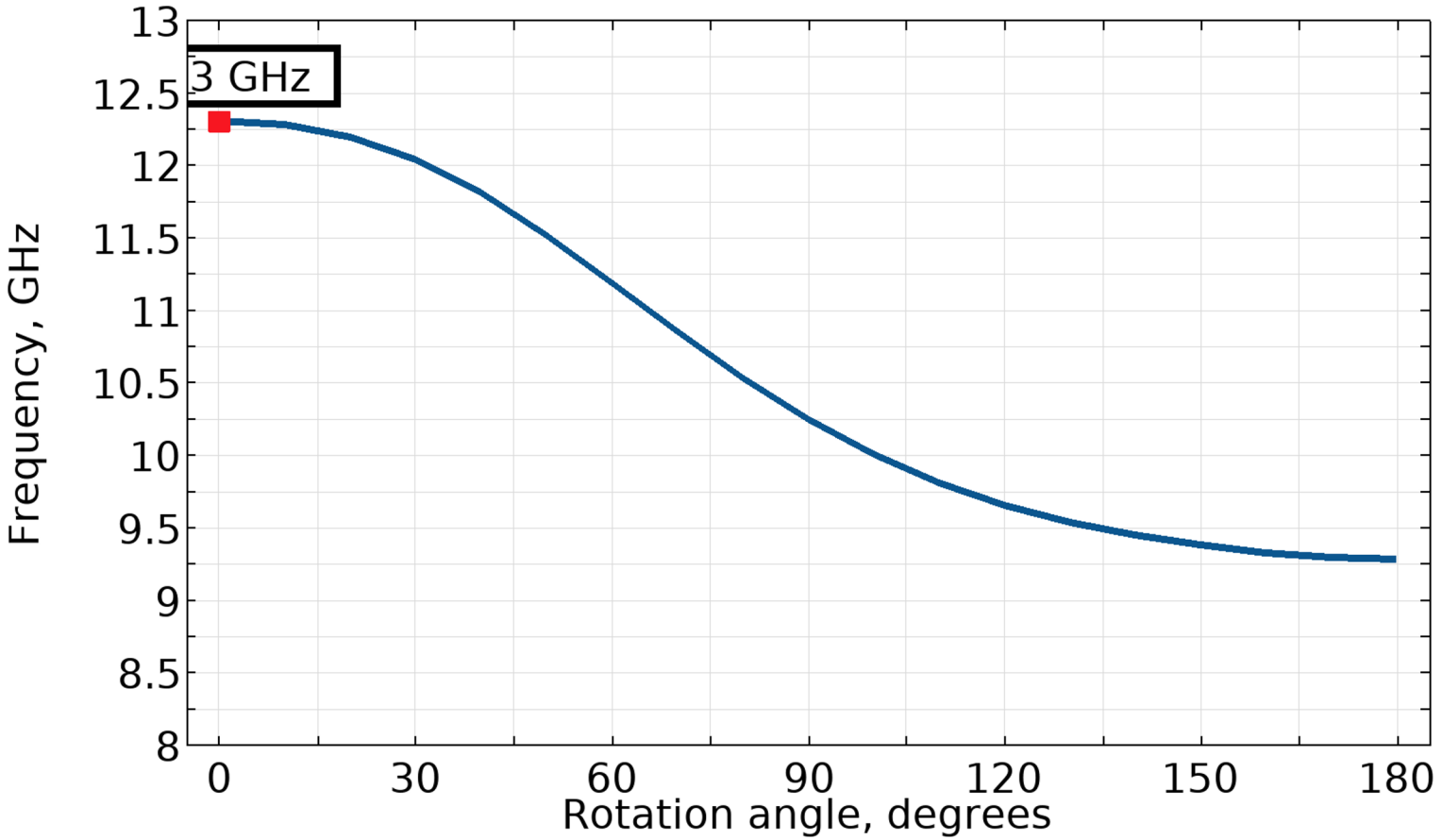
PROTOTYPE I

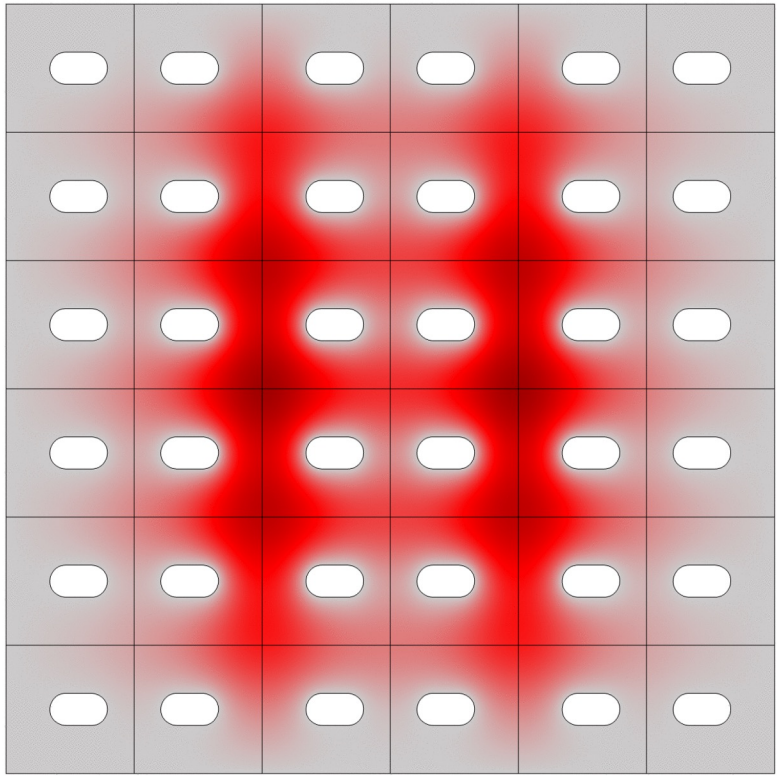




PROTOTYPE II

STOCKHOLM UNIVERSITY: TUNING



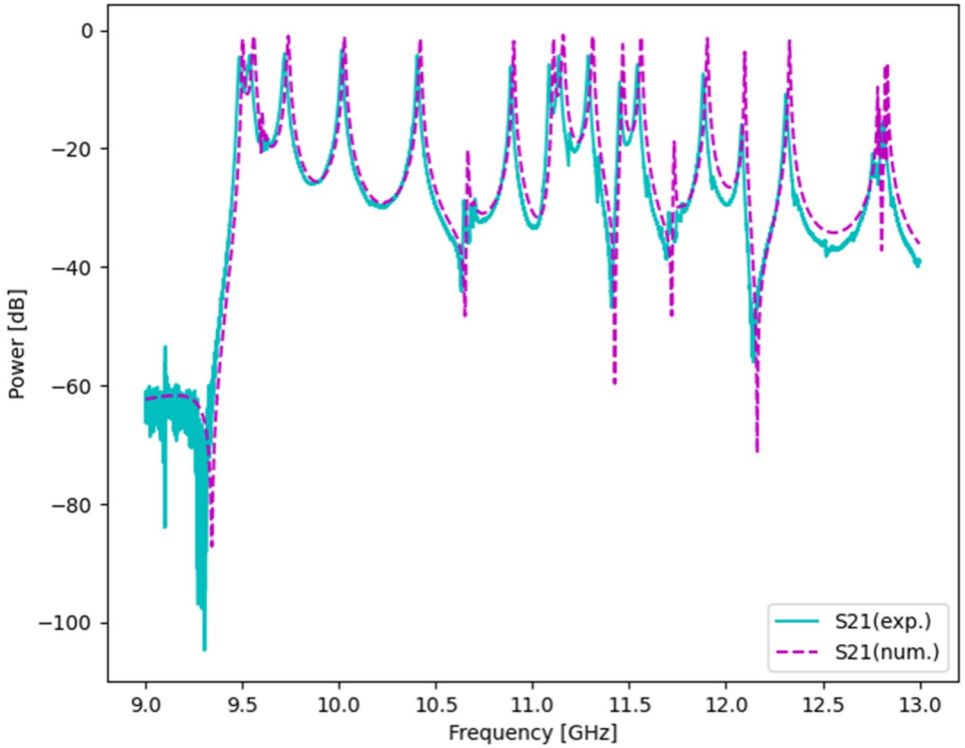


Tuning with sails

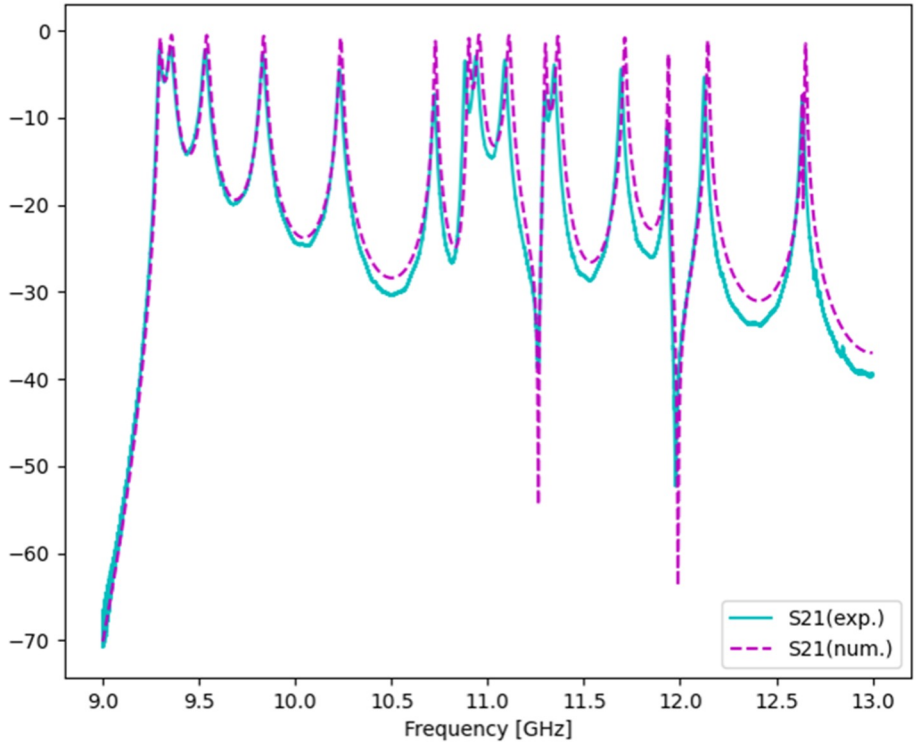
Theory and simulations from the ITMO/St. Petersburg group
(R. Balafendiev, P. Belov, M. Gorlach, et al.)

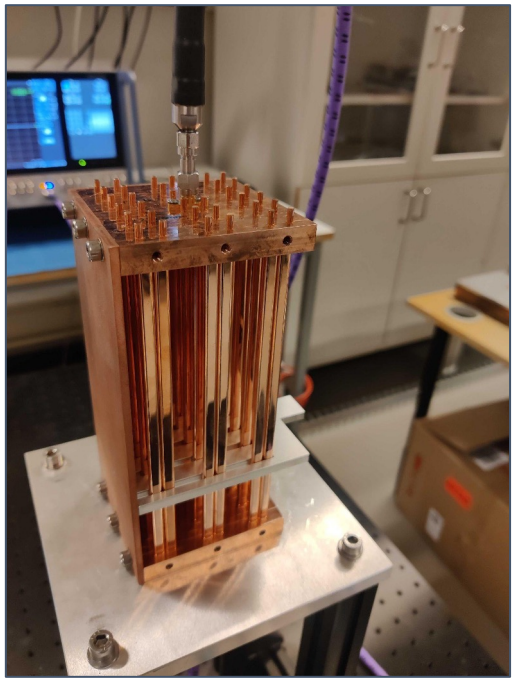
STOCKHOLM UNIVERSITY: TUNING

$\theta = 135°$



$\theta = 180°$

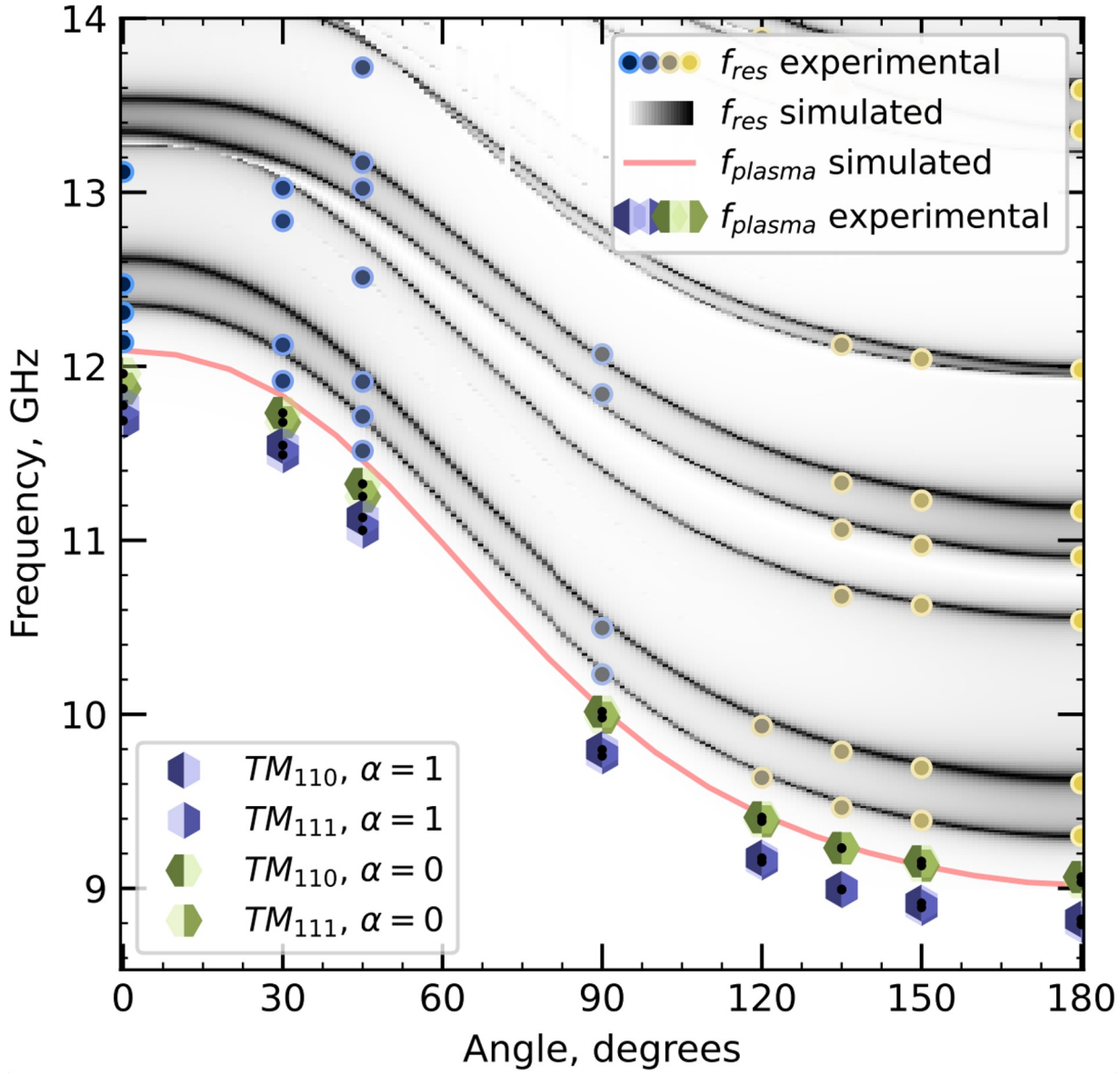




Tuning with sails

R&D towards optimized FOM actively pursued at Stockholm University (G. Kaur.)

STOCKHOLM UNIVERSITY



Phase Ib resonator

- Theory and simulation agree
- Scalable to arbitrary volumes
- R&D ongoing for tuning mechanism
- 28% tuning range (9.3 – 12.1 GHz)
- No unwanted TE or TEM modes

>>> NEXT: Cryogenic testing

CURRENT STATUS

Construction of ALPHA under way

Experiment hosted at Yale

16.4 Tesla superconducting magnet

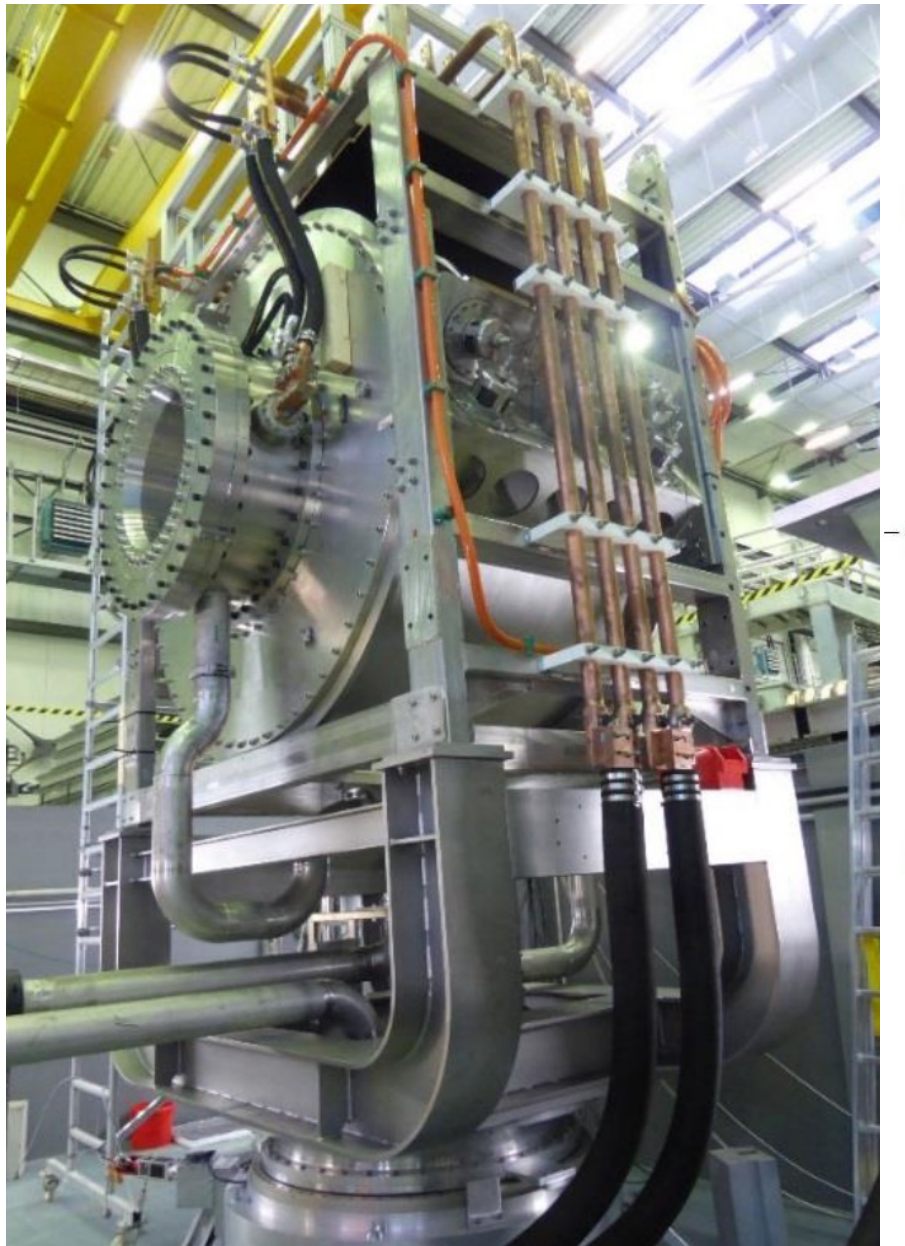
Commissioning 2026-27

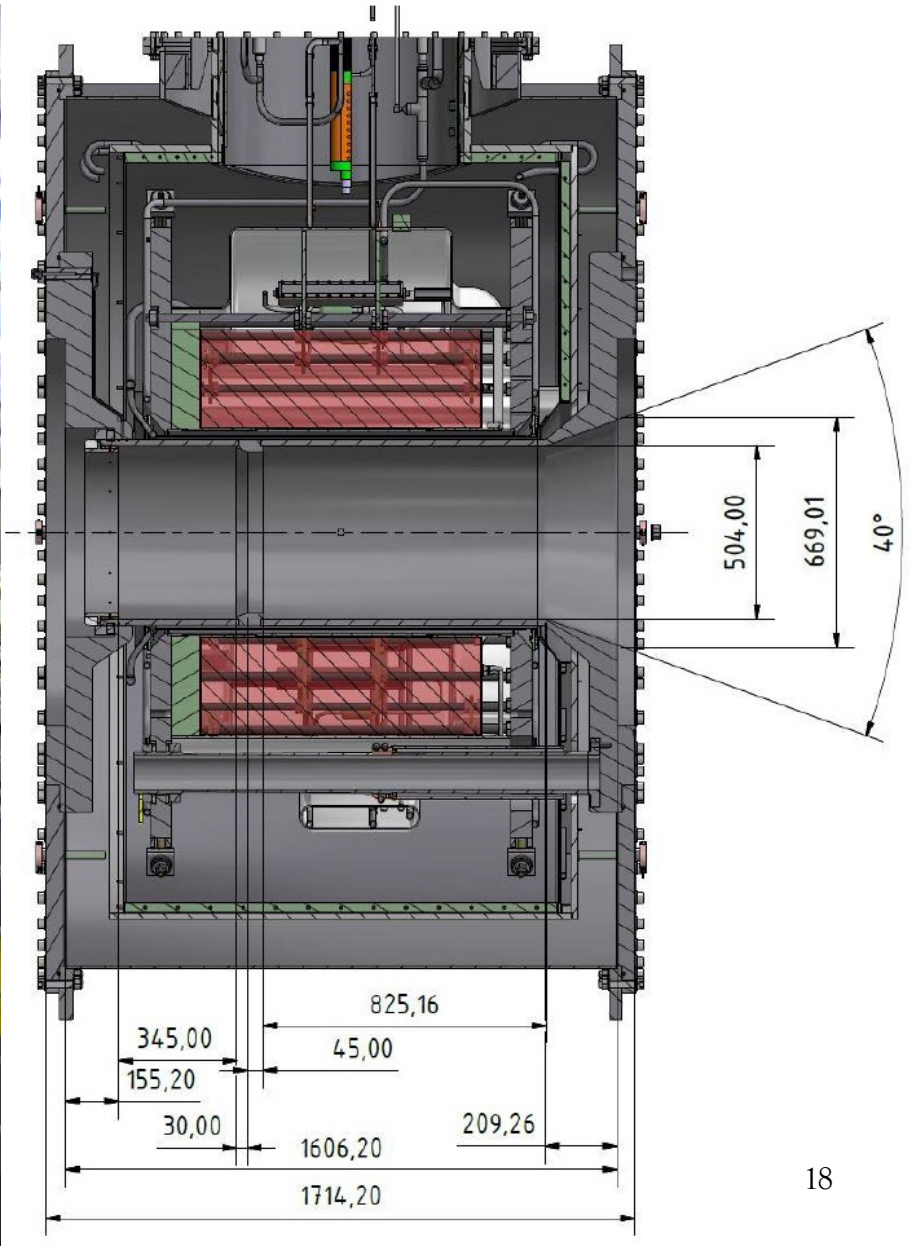
ALPHA 2.0: MAGNET FROM HZB TO ORNL

13 T magnet from HZB

50 cm ∅ × 170 cm

From 2024
> 10 y of scientific use





CONCLUSIONS

Search for axionic dark matter

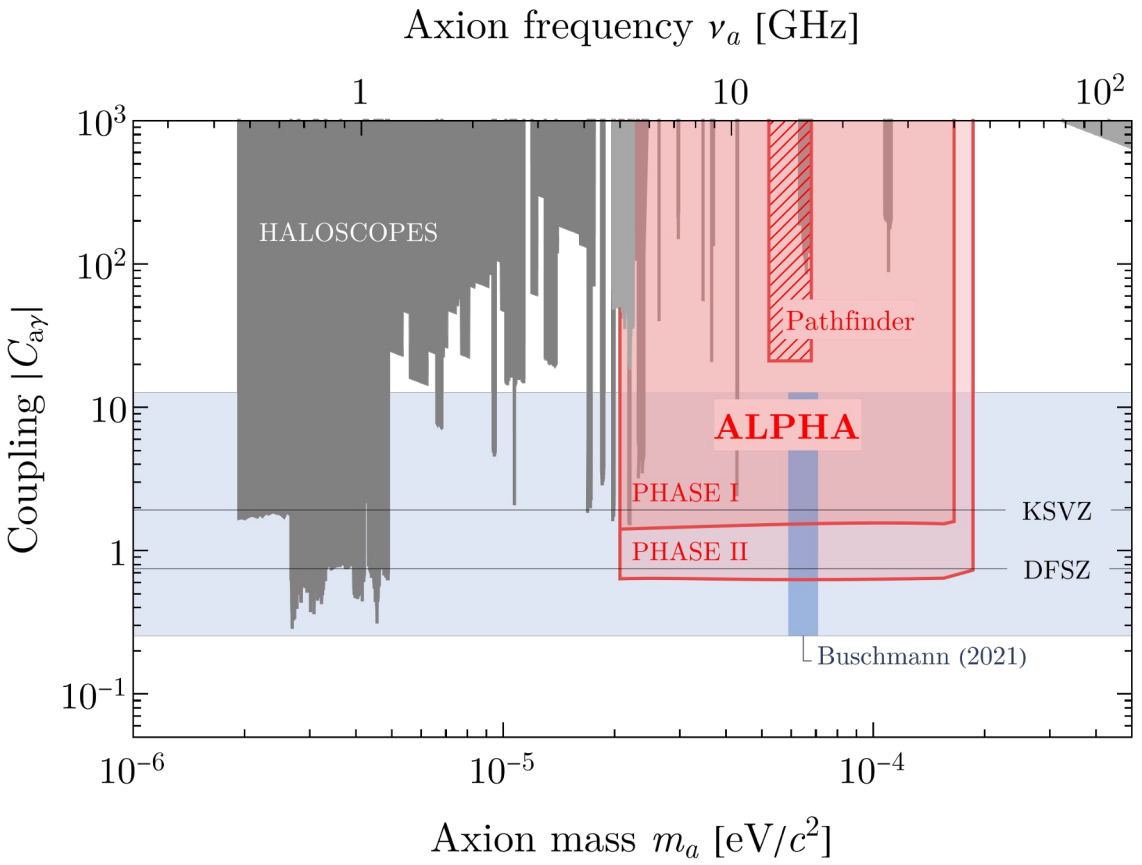
Mass range 40-80 μeV
Compelling case for post-inflations axions

R&D and technology

Innovative solutions in microwave technology
Synergies with multiple branches of physics

The ALPHA experiment

Construction underway!
Commissioning 2026-27




Physics
@BERKELEY
YALE

THE ALPHA COLLABORATION

Collaboration Institutions

Yale University (Host)
Arizona State University
University of California Berkeley
University of Cambridge
Colorado University
Iceland University
ITMO University
Johns Hopkins University
Massachusetts Institute of Technology
Oak Ridge National Laboratory
Stockholm University
Wellesley College

Project Scientist:
F. Wilczek (MIT/Stockholm University)
Project PI:
K. van Bibber (Berkeley)
Project Technical Director:
M. Jewell (Yale)
Spokes / deputy persons:
J. Gudmundsson (Stockholm University)
R. Maruyama (Yale)

Support gratefully acknowledged by

John Templeton Foundation
Inspiring Awe & Wonder
Simons Foundation
Knut och Alice Wallenbergs Stiftelse
Swedish Research Council
Olle Engkvists Stiftelse