Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

DESY.

Fermilab SQMS

The MAGO cavity and prospects for high-frequency GW searches

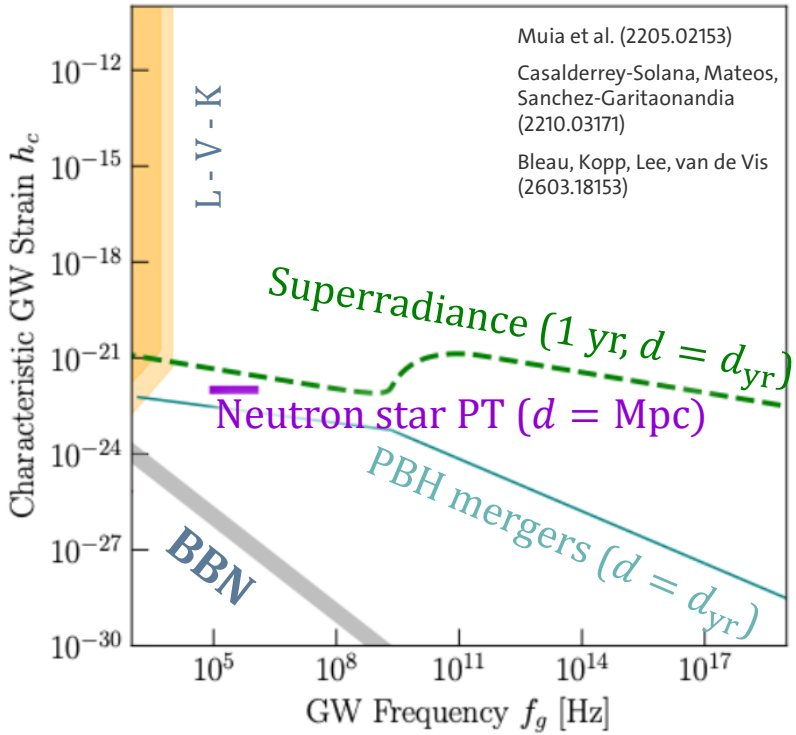
Giovanni Marconato – for the MAGO 2.0 collaboration

Milan, 17 June 2026

Outline

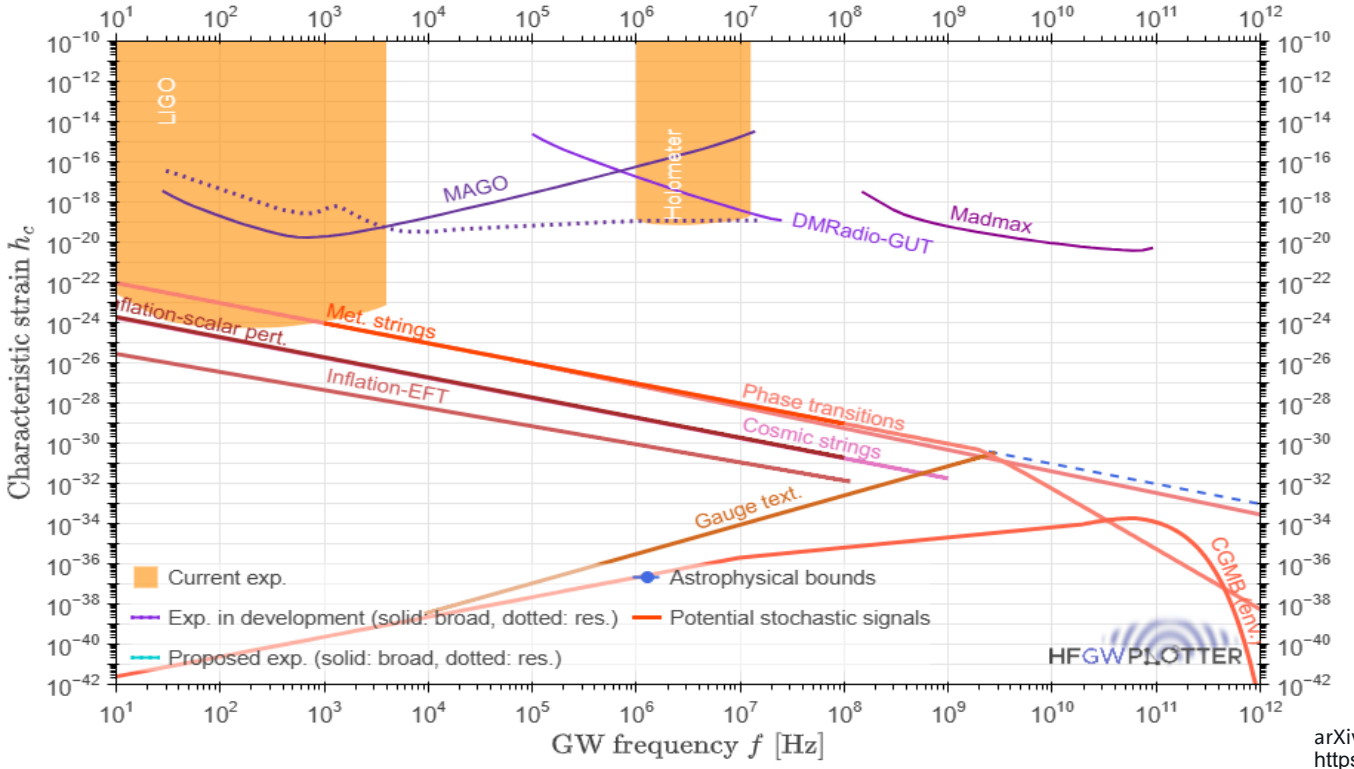
- Why look at High Frequency GW?
- Detection principle
- System characterization
  Requirements & Results
- Future perspectives

Why look above 10 kHz?



- Extend measurements to higher frequency
  - complementary to L-V-K
- No astrophysical foreground
  - search for BSM physics
- Long term goal:
  - measure the CGB (Cosmic Gravitational wave Background)

Sensitivity prediction



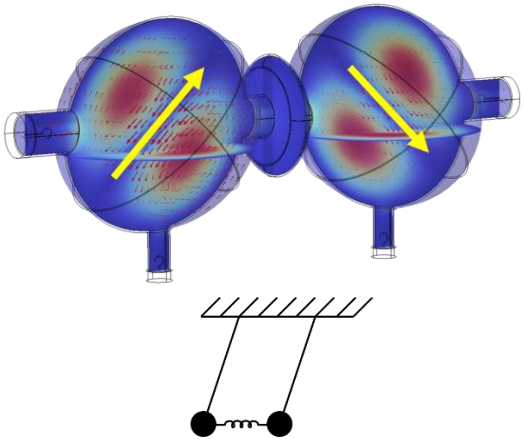
- Possibility to store more energy than optical cavities
- Small scale detector
- Big margin for optimization

arXiv:2501.11723v2
https://incandenza-01.zdv.uni-mainz.de/Omegaplot/

Detection principle

STEP 1

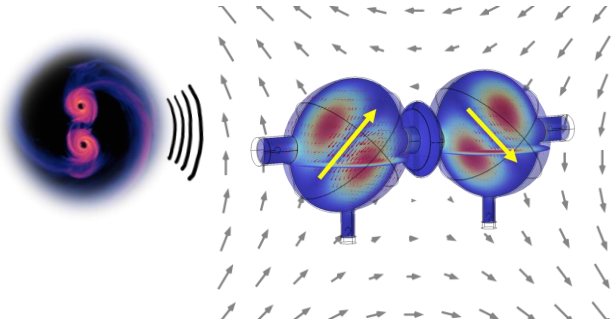
Drive only the
0 mode
(in-phase mode)



STEP 2

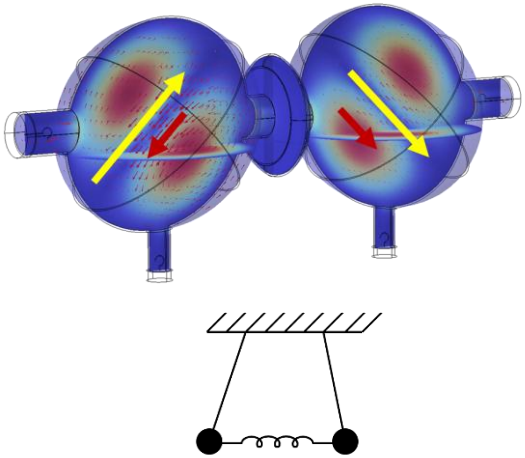
GW → Mechanical → RF

The **vibration** of the walls from **GW** produces an **upconversion of** the **RF signal** to a higher frequency

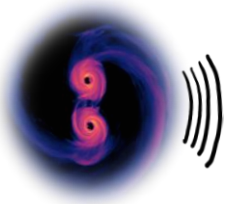


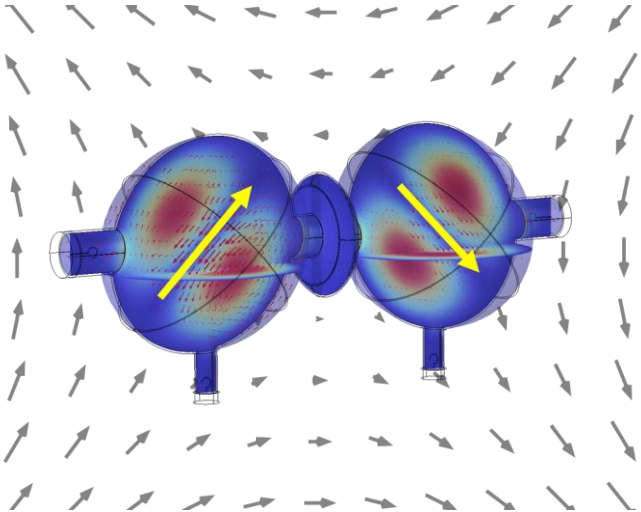
STEP 3

Read only the
π mode
(out-of-phase mode)

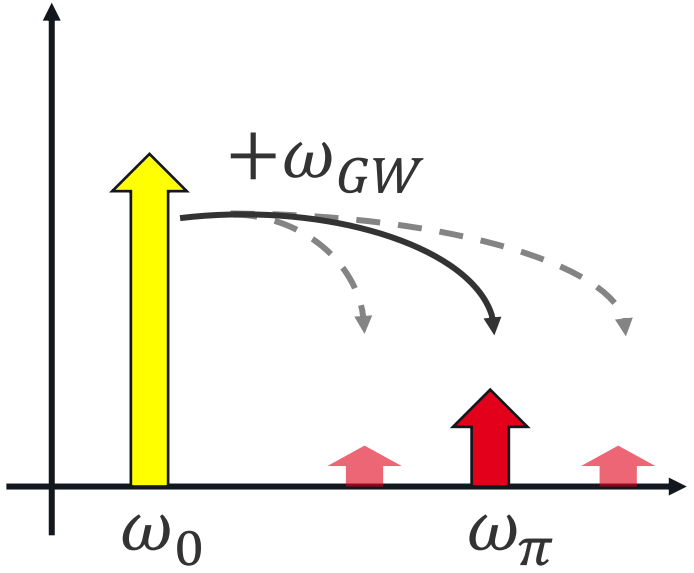


Detection principle

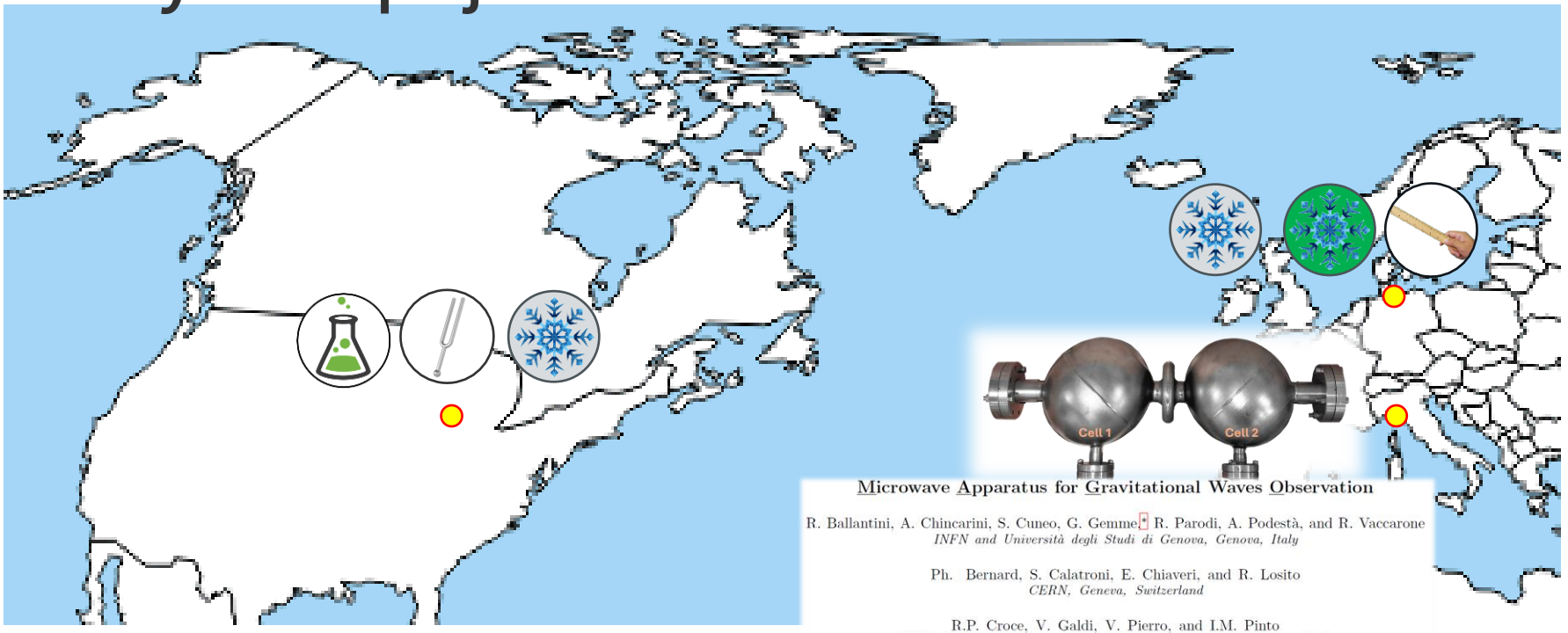




GW → Mechanical → RF



History of the project



Microwave Apparatus for Gravitational Waves Observation

R. Ballantini, A. Chincarini, S. Cuneo, G. Gemme,* R. Parodi, A. Podestà, and R. Vaccarone
INFN and Università degli Studi di Genova, Genova, Italy

Ph. Bernard, S. Calatroni, E. Chiaveri, and R. Losito
CERN, Geneva, Switzerland

R.P. Croce, V. Galdi, V. Pierro, and I.M. Pinto
INFN, Napoli, and Università degli Studi del Sannio, Benevento, Italy

E. Picasso
INFN and Scuola Normale Superiore, Pisa, Italy and
CERN, Geneva, Switzerland

Cavity preparation

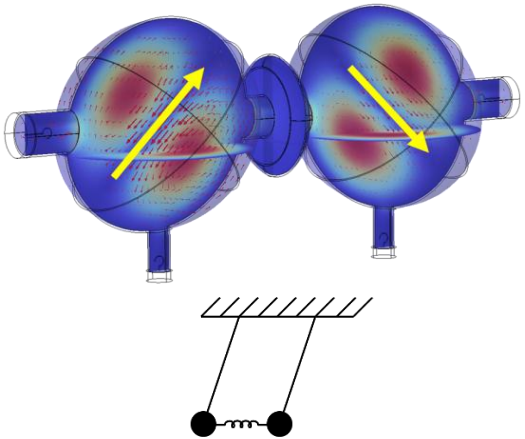
- After “resting” for >15 years the cavity needed precise mechanical tuning
- Single cell frequency tuning to achieve coupled system with desired mode splitting for GW detection

Fischer et al., Class. Quantum Grav. 42 115015 (2025)

Detection principle

STEP 1

Drive only the
0 mode
(in-phase mode)



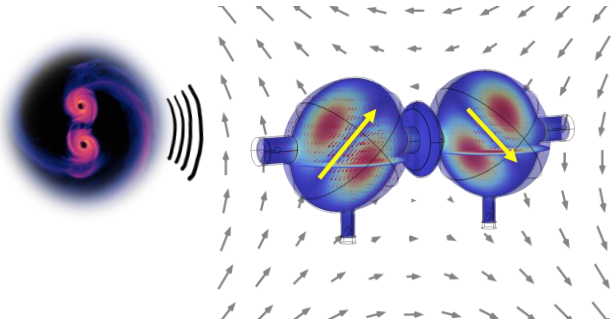
STEP 2

GW → Mechanical → RF

Th[illegible]lls

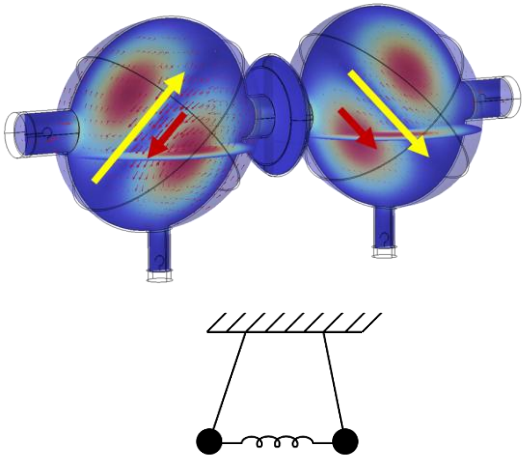
RF characterization

upc[illegible]gnal
to a higher frequency

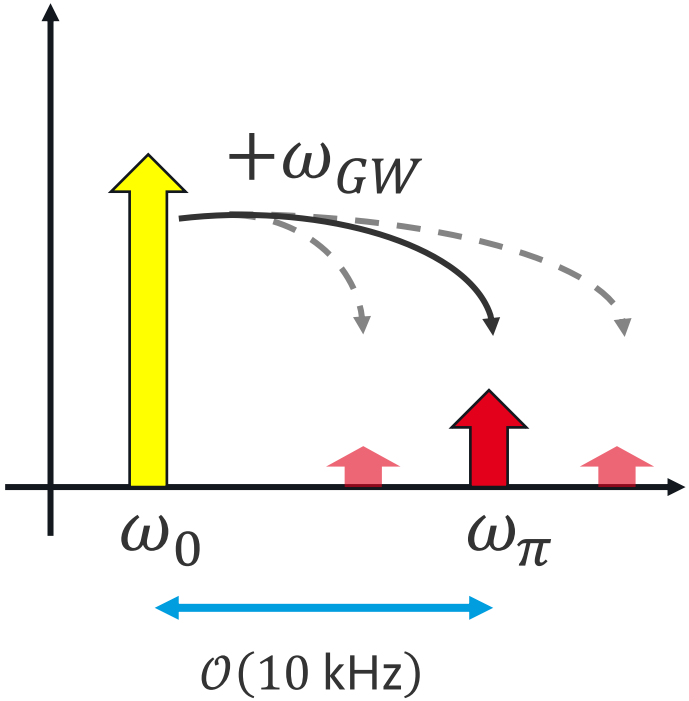


STEP 3

Read only the
π mode
(out-of-phase mode)



Mode splitting requirements

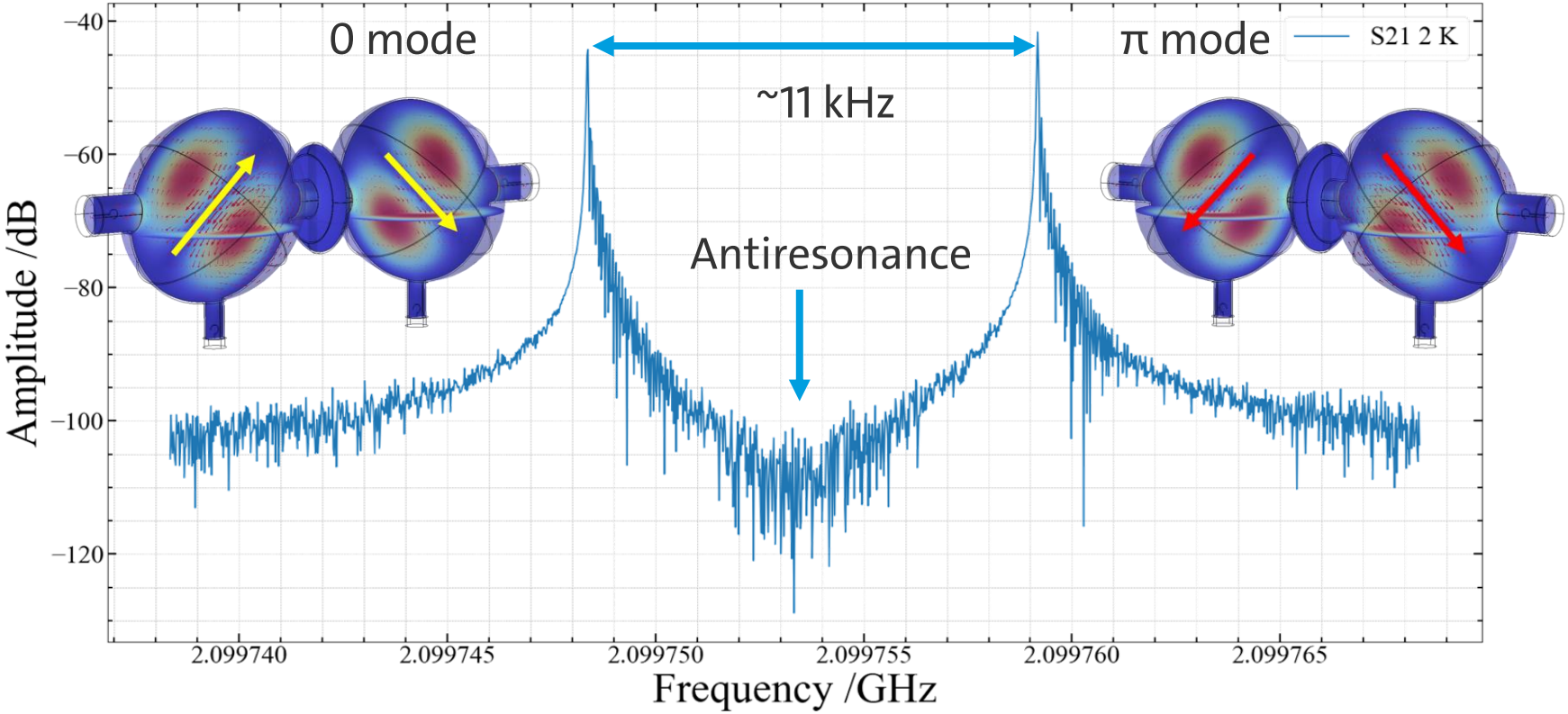


- Mode separation close to frequency of GW of interest

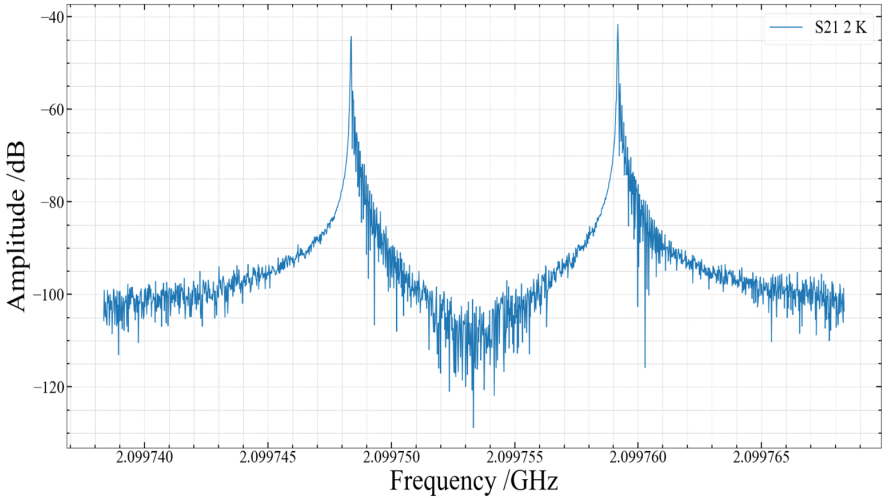
$$\omega_0 \sim 2.1\ GHz$$

$$\omega_{GW} \sim 10\ kHz$$

Mode splitting results



Quality factor requirements

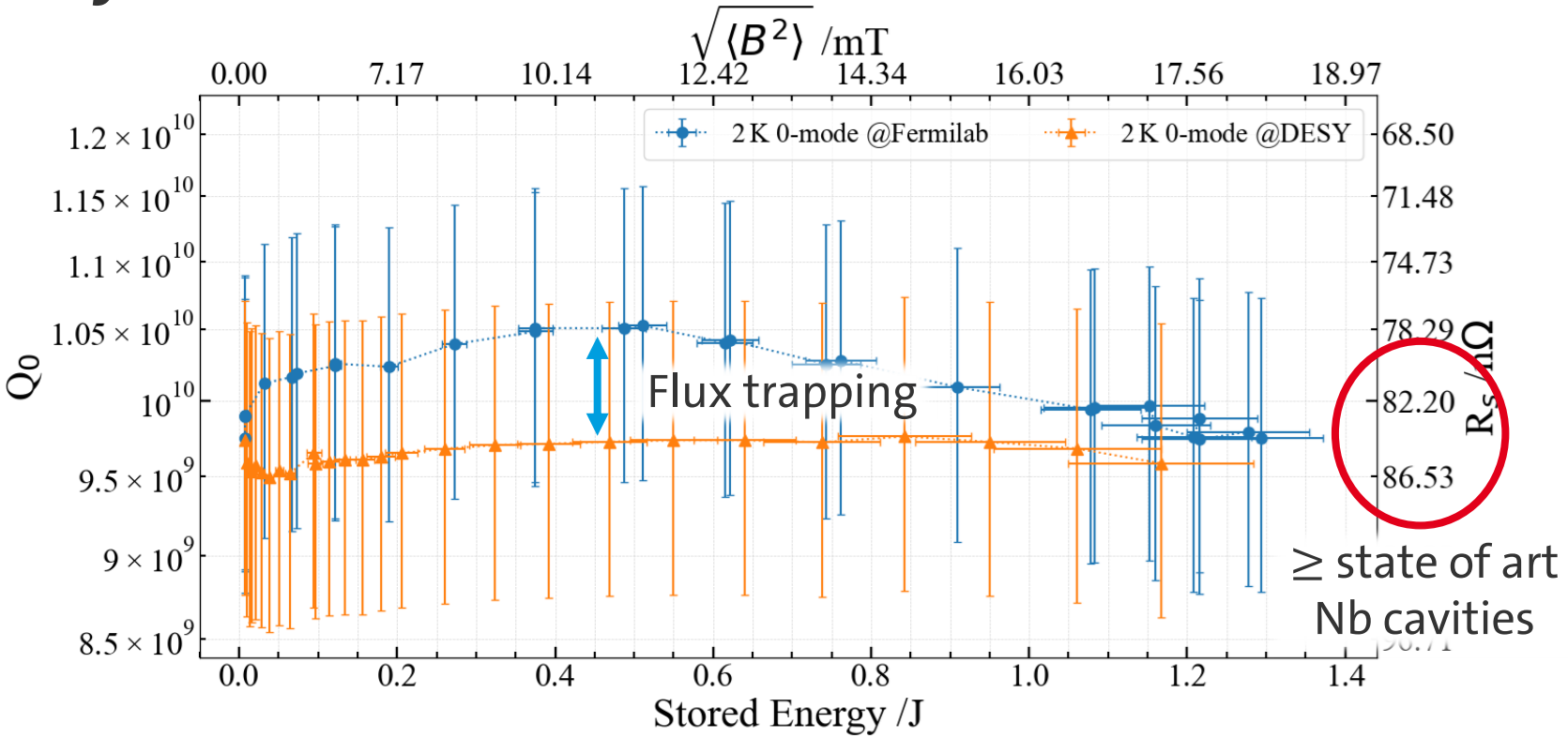


- Sharp resonance bandwidth required to resolve signals with this frequency separation

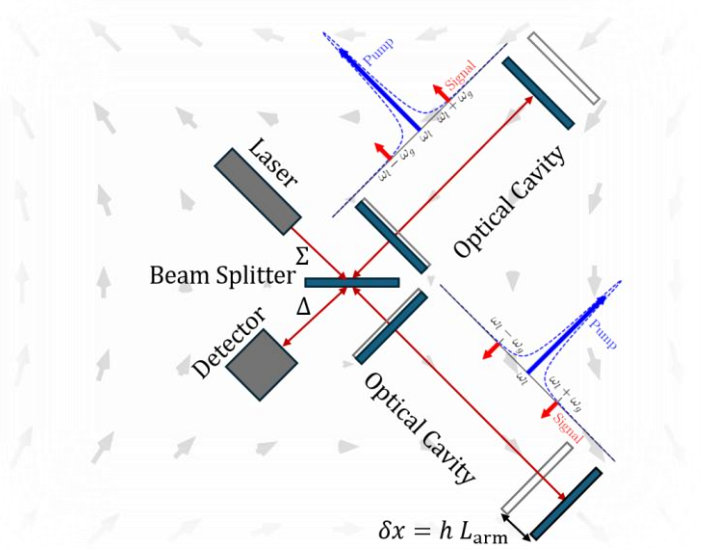
$$\omega_\pi - \omega_0 \sim 11\ kHz$$

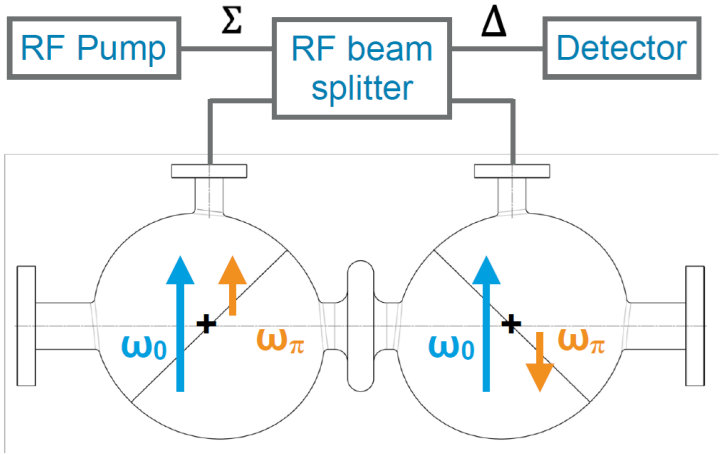
$$\frac{\omega}{BW} = Q_0 \sim \frac{GHz}{Hz} \rightarrow 10^{10}$$

Quality factor results



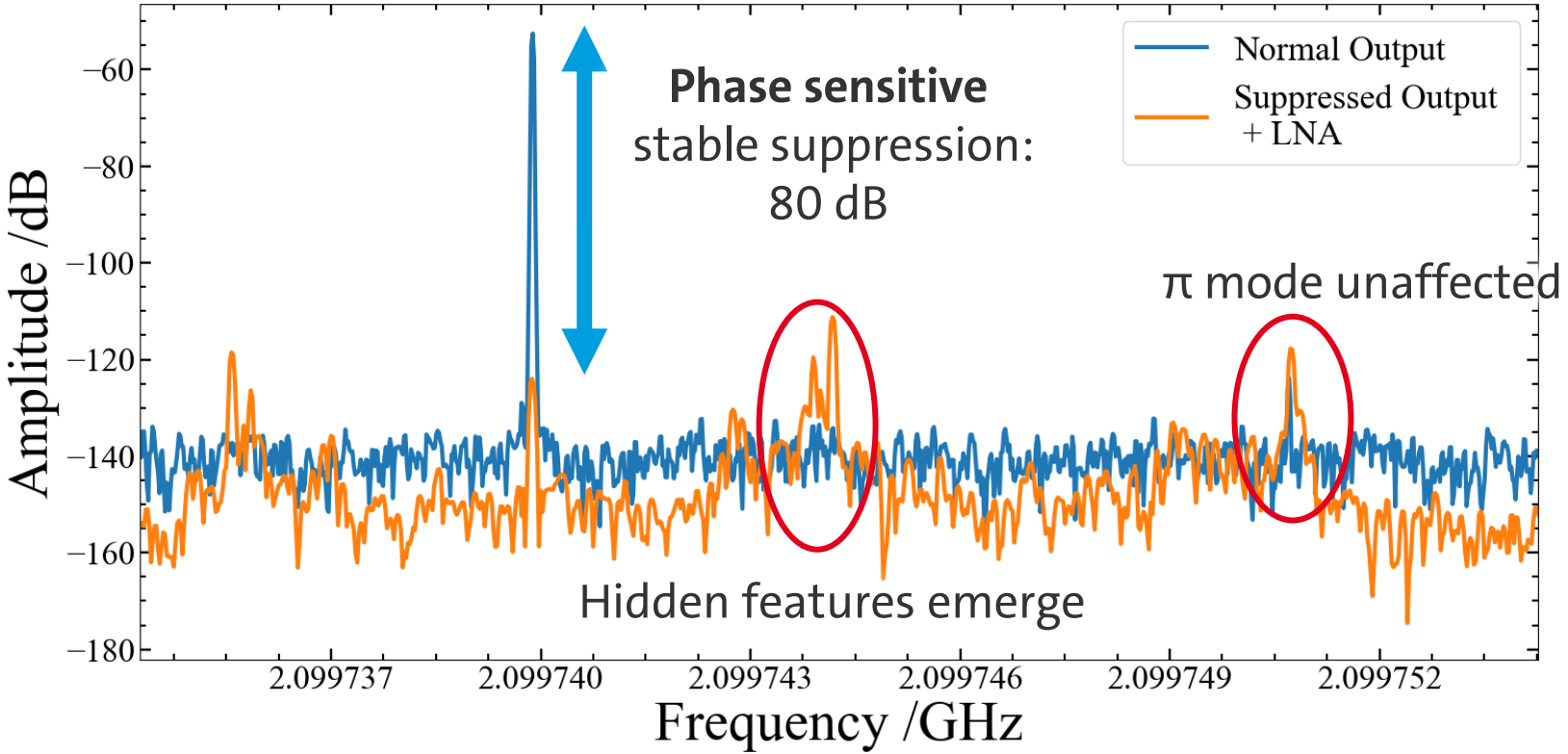
Signal discrimination requirements





- Signal discrimination based on phase
  → RF equivalent of interferometer beam splitter

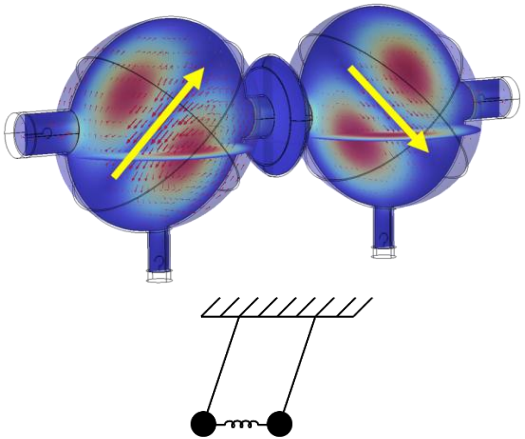
Signal discrimination results



Detection principle

STEP 1

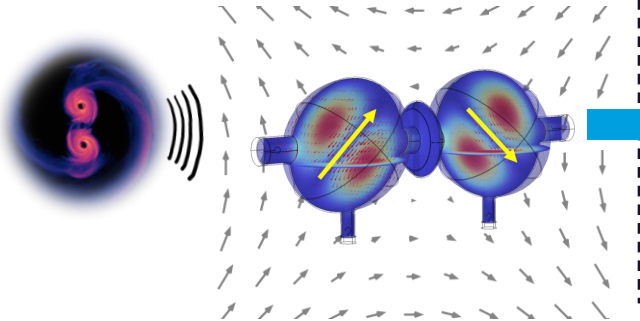
Drive only the
0 mode
(in-phase mode)



STEP 2

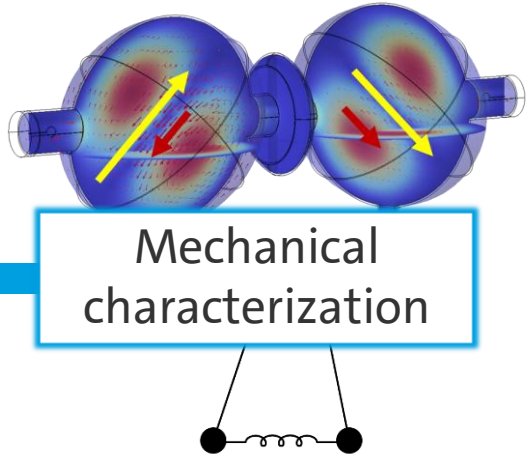
GW → Mechanical → RF

The **vibration** of the walls from **GW** produces an **upconversion of** the **RF signal** to a higher frequency



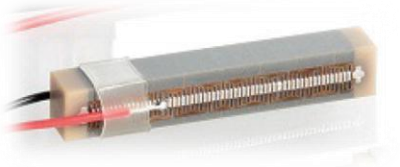
STEP 3

Read only the
π mode
(out-of-phase mode)

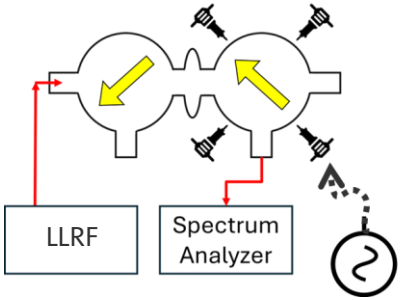


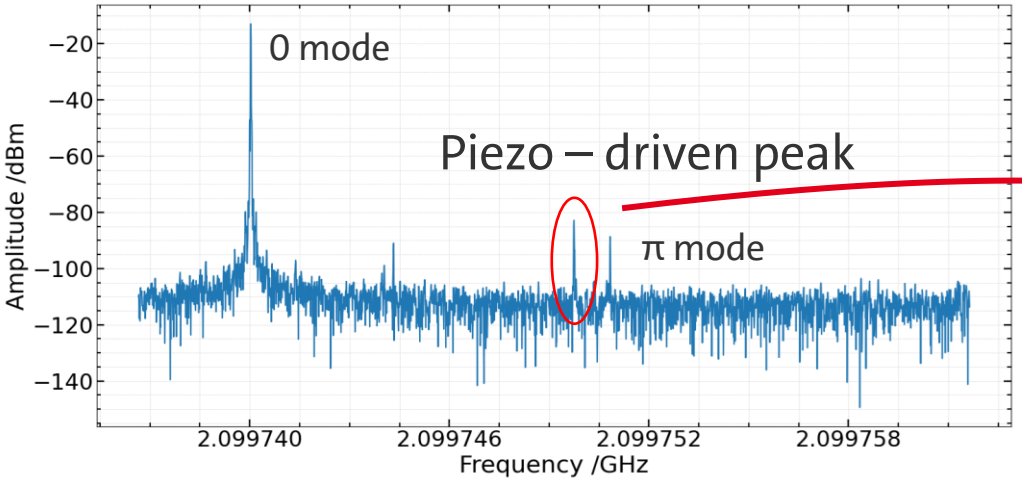
Mechanical characterization

- Install piezoelectric actuators to:
  - Excite mechanical vibrations at desired frequency
  - Study mechanical to RF conversion
- **Fake Gravitational Wave!** for system calibration

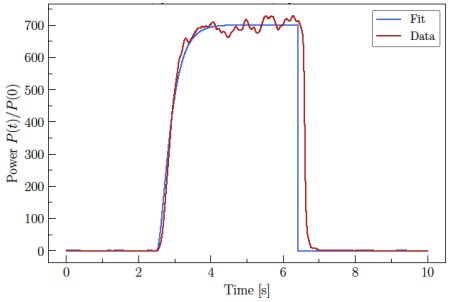


Mechanical to RF signal

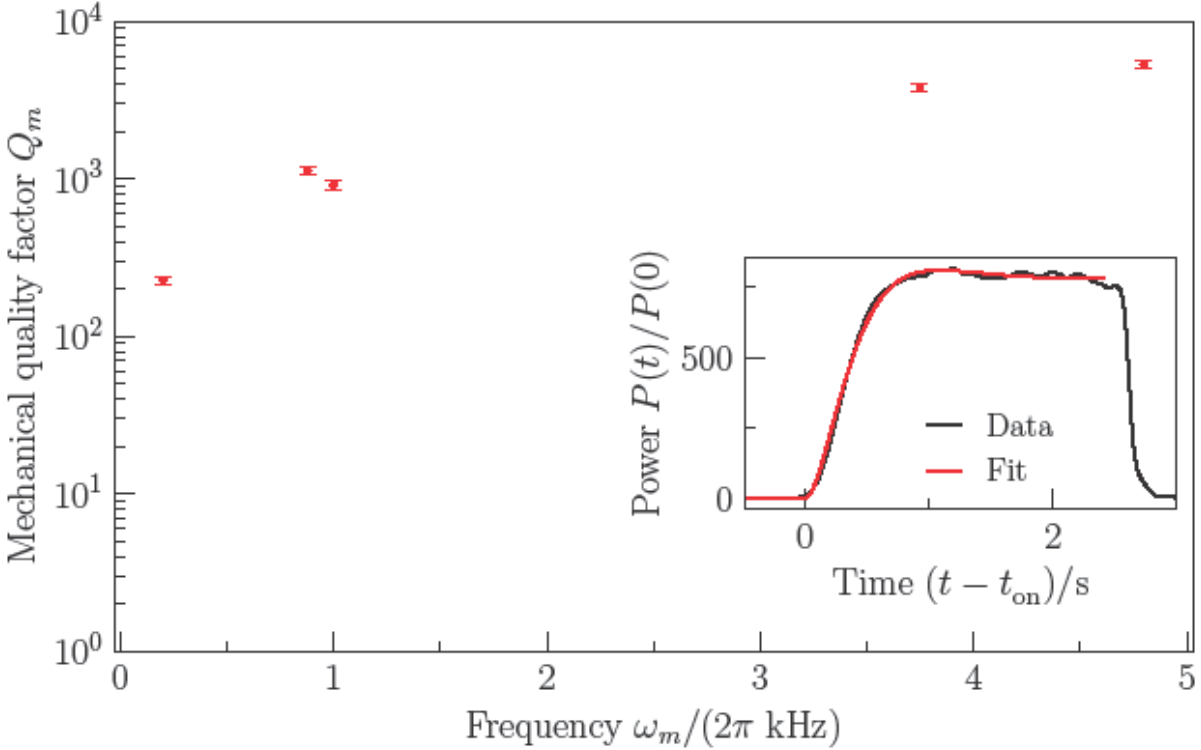




- Drive 0 mode with Low Level RF system
- Drive piezos with signal generator in “PULSE” mode
- Readout time domain RF signal



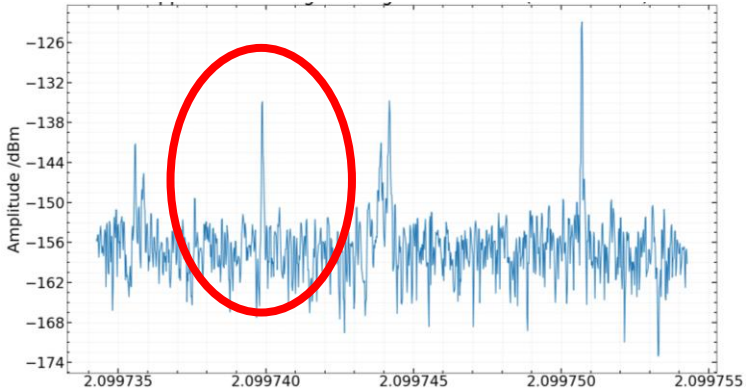
Mechanical Quality factor

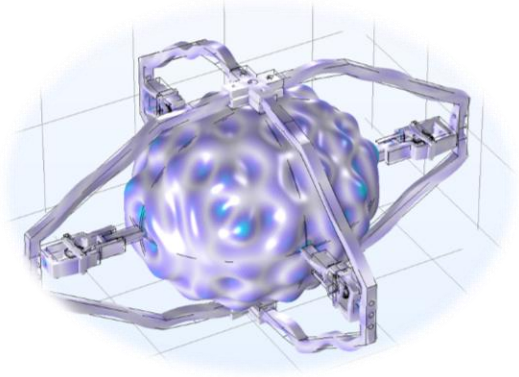


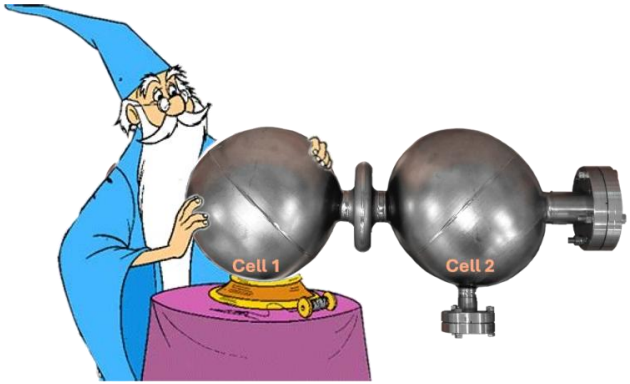
- Far from EM resonance
  - ➢ Q_m dominates
- Theoretical calculation assumed
  $$Q_m = 10^5$$
- Measurement reflects contributions of the whole system

Future perspectives

- **Improve current prototype:**
  - Improve RF suppression system
  - Characterize cavity mechanical modes
  - Create controlled “Fake GW” signal for calibration



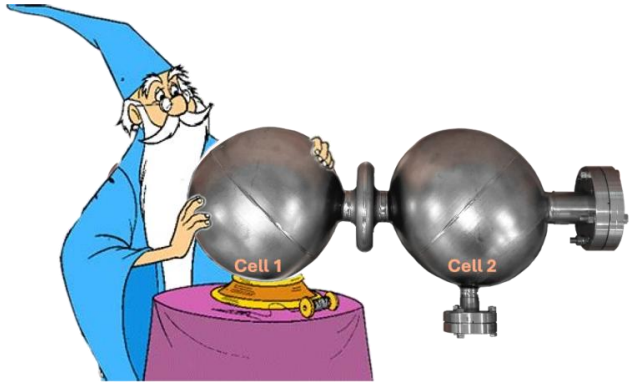




Future perspectives

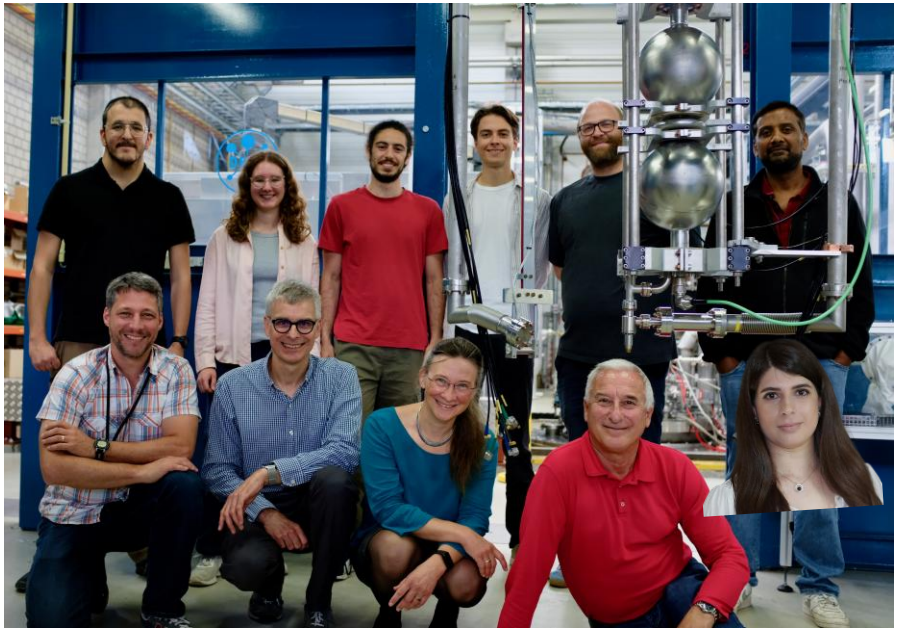
- **Next generation cavity:**
  - ❖ Design a new prototype with optimized sensitivity to GW
  - ❖ Implement mechanical noise insulation in cryostat

    ↳ Less strict requirements than interferometers due to different frequency range



Summary

- Successfully characterized and tuned old prototype cavity
- Successful implementation of phase sensitive **suppression** $\sim 80\ dB$
- Design of next generation cavity with higher coupling to GW



Thank you!

Project collaborators: Julien Branlard, Vijay Chouhan, Can Docuyucu, Sebastian Ellis, Lars Fischer, Bianca Giaccone, Ivan Gonin, Anna Grassellino, Wolfgang Hillert, Matthias Hoffmann, Timergali Khabiboulline, Tom Krokotsch, Frank Ludwig, Uros Mavric, Gudrid Moortgat-Pick, Yuriy Orlov, Krisztian Peters, Sam Posen, Oleg Pronitchev, Andreas Ringwald, Udai Singh, Marc Wenskat