FERMILAB-SLIDES-23-288-SQMS

Status of MAGO activities at Fermilab

Bianca Giaccone, On behalf of SQMS Fermilab Physics and Sensing

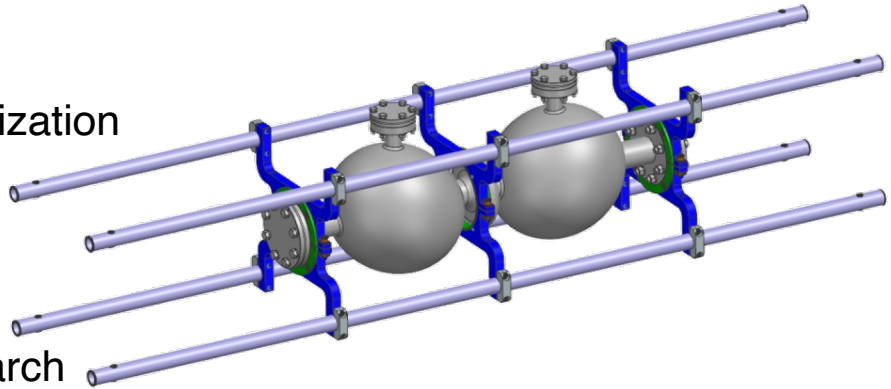
Sept 4, 2023

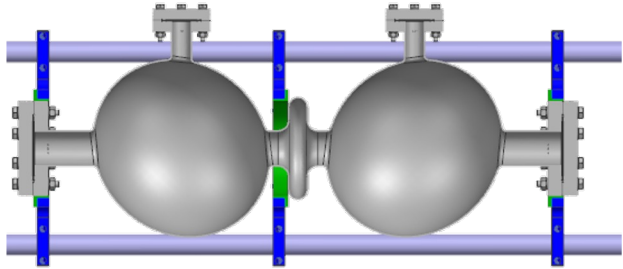
We are preparing for the cavity arrival

R. Ballantini et al., arXiv:gr-qc/0502054 (2005)

In order to be able to prepare and cold test the MAGO cavity:

- Many steps are necessary:
  - Assembly cage
  - HPR: system compatibility and possibly optimization
  - Polishing: BCP vs EP
  - Heat treatment
  - Flanges (for VTS: RAV & burst disk)
  - RF antennas for first cold test and for GW search
  - Cage for cold tests
  - Cold test pressure simulations
  - Check compatibility with existing RF system ($TE_{011} \approx 2GHz$)
  - Tuning: warm and cold
    - Coupling cell
    - Spherical cells
  - …





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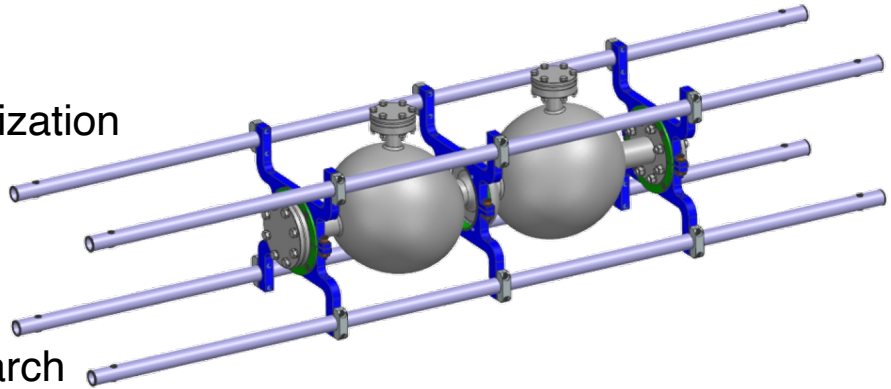
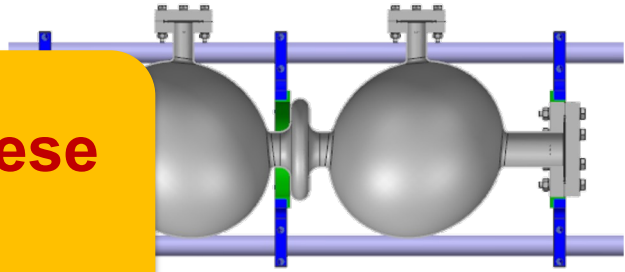
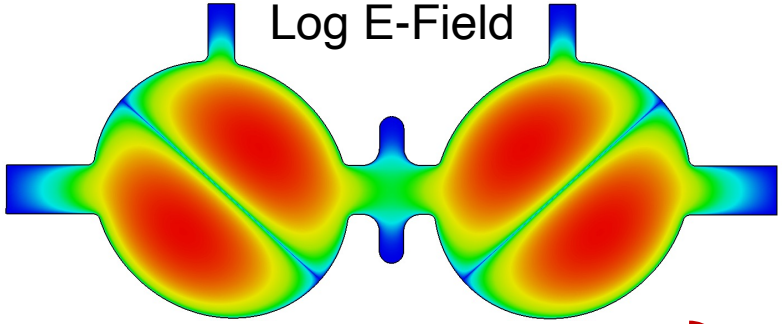




We are working on all these aspects already!

RF simulations → TE_{011}: 3 pairs of modes

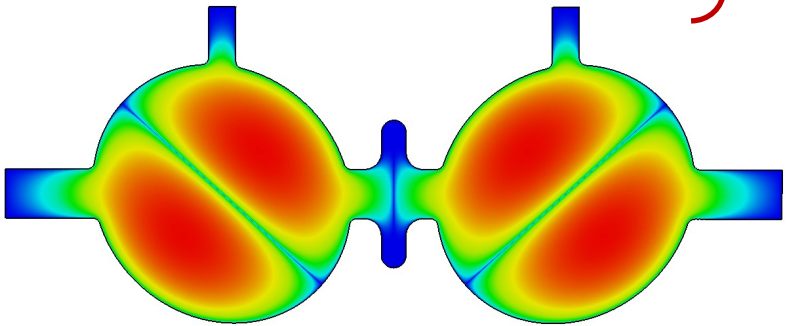
Log E-Field



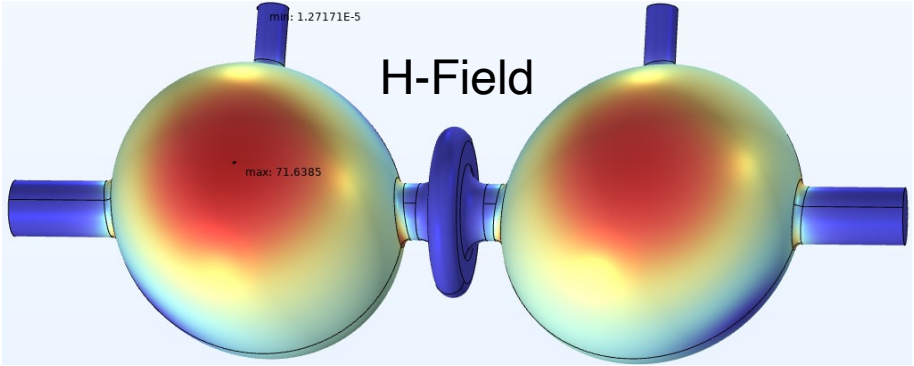
"0" mode F=2.103683 GHz

Δf=10KHz

"π" mode F=2.103693 GHz



"π" mode F=2.076760 GHz



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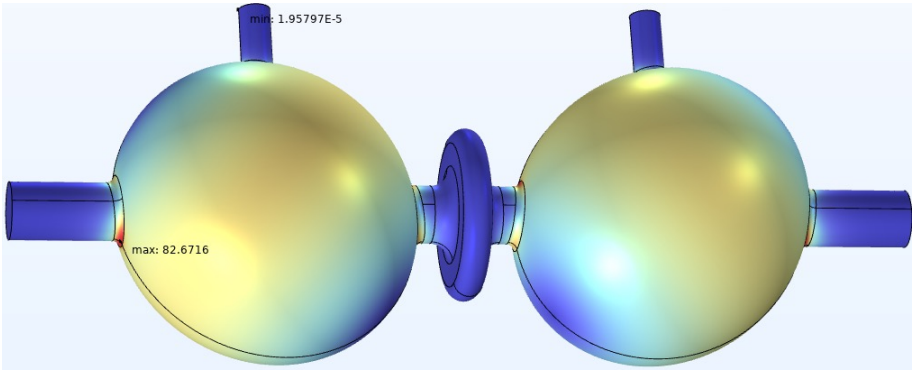
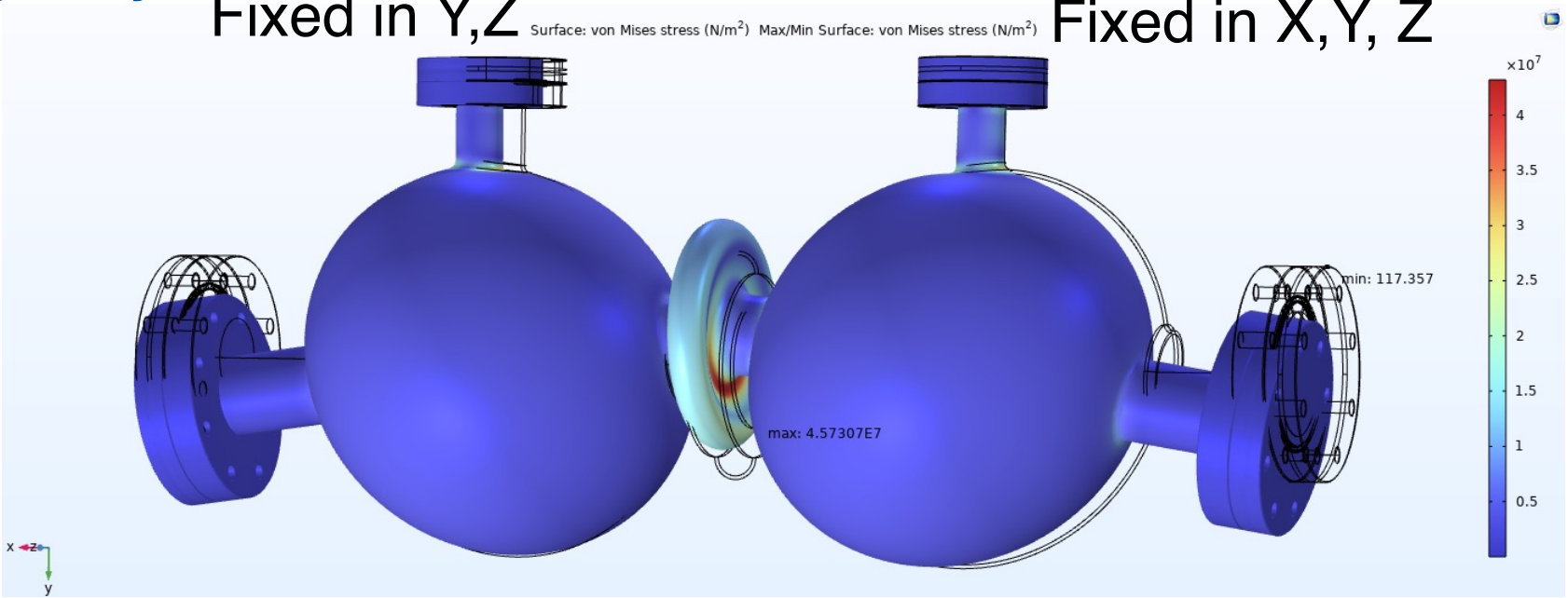


Mechanical simulations: effect of cavity under vacuum & subject to gravity

Fixed in Y,Z



Fixed in X,Y, Z

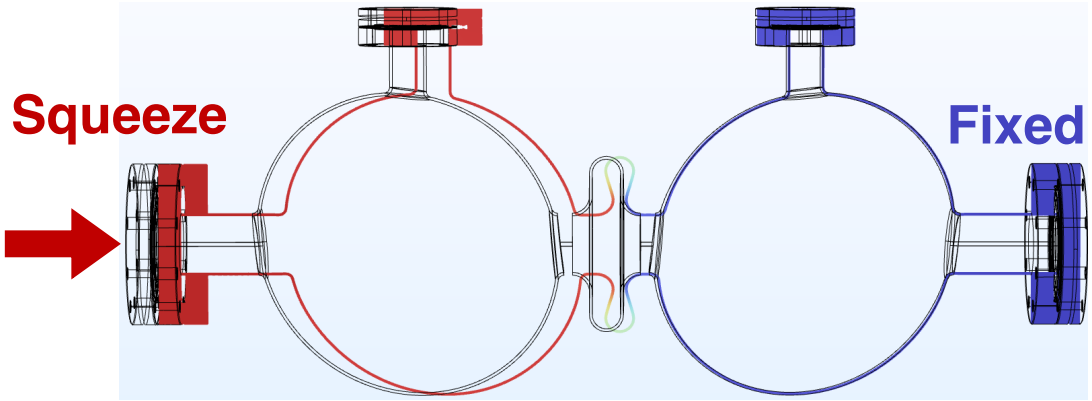
Mechanical simulations: effect of cavity under vacuum & subject to gravity

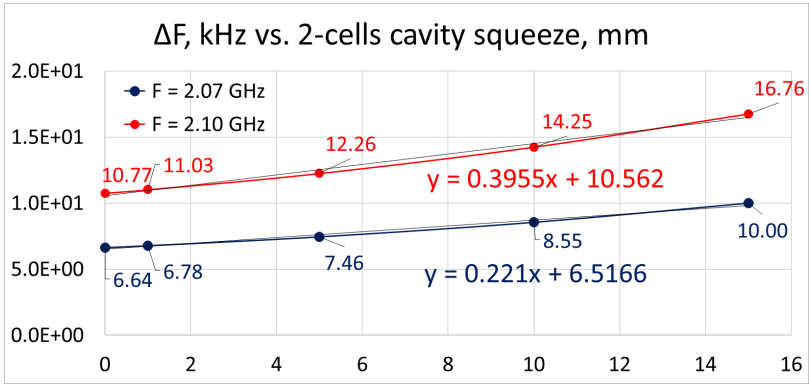
Fixed in Y,Z

Fixed in X,Y, Z

We always brace and restrain our SRF cavities, but in this case is even more crucial!

RF + mechanical simulations



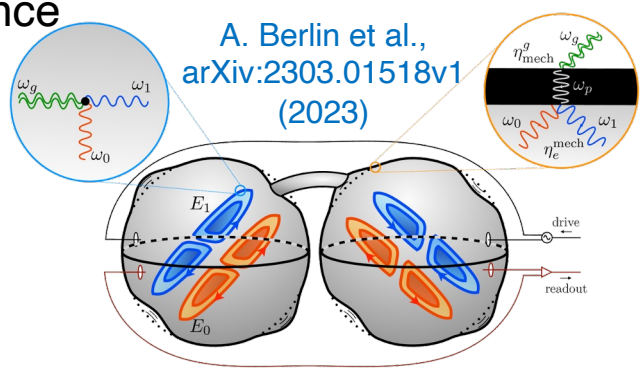


Now: leveraging the expertise of our incredible RF team to **simulate coupled oscillators** subject to **mechanical vibrations** (induced by GW or ambient noise) and derive **expected growth rate of the signal mode** due to parametric energy transfer from pump mode for the three pairs

We are excited to collaborate with INFN and DESY to revive the MAGO experiment and use the acquired experience to inform the design of the next SRF-based GW searches

Looking forward: MAGO 2.0

- Planning for a broadband non-resonant search
- Working to gain better understanding of sensitivity to GW strain on:
  - GW frequency detuning from cavity mechanical resonance
  - Imperfections in cavity shapes and asymmetry between coupled cells
  - Microphonics and high frequency vibrational noise
  - Amplifier noise
  - …



- Currently focusing on design phase for an optimized cavity geometry and tuning system and planning to leverage lessons learned from MAGO 1.0
- US/Japan collaboration → small effort between SQMS Fermilab and University of Tokyo & KEK for SRF based GW searches
- Worth looking into custom cryostat and suspension design

In the case of GW searches is particularly important to have a **series of coordinated and synchronized experiments taking place at different locations**

MAGO 2.0 could be a global experiment involving many laboratories!

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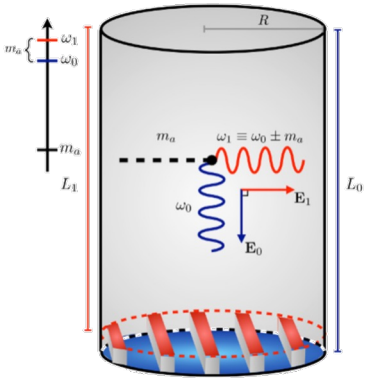
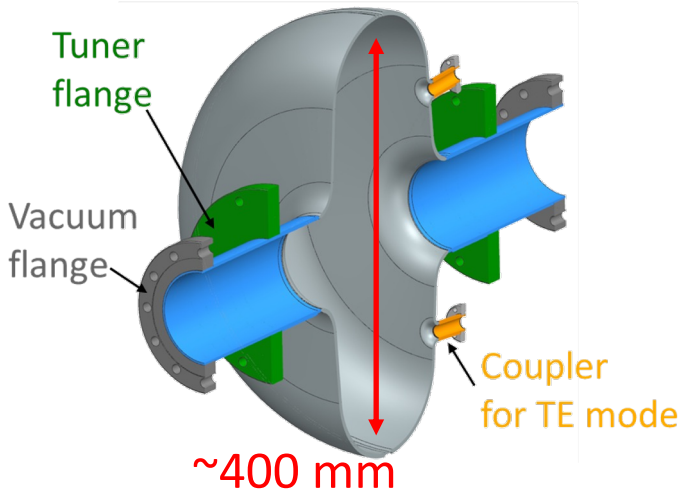
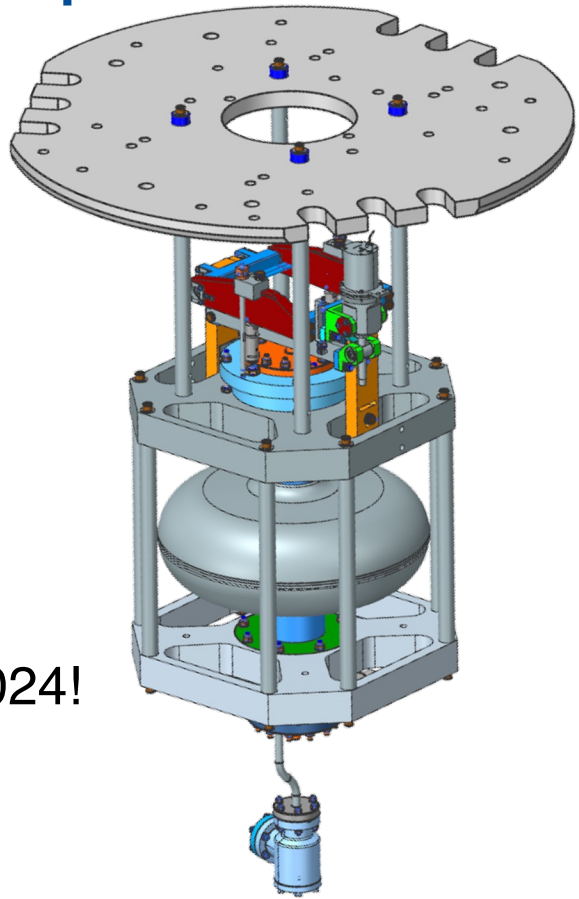
On a slightly different but connected topic…

Heterodyne axion DM search: from theory to experiment



A. Berlin, et al., Journal of High Energy Physics 2020.7 (2020)





- Design is completed, currently procuring 2 prototype cavities

→ expected to arrive by end of 2023/beginning of 2024!

- Pump mode: TM_{020}, Signal mode: TE_{011}
  - By design: $\Delta f \approx 1$MHz
  - Tuner: same design as Dark SRF tuner

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Thank you!

The **Fermilab SQMS Physics and Sensing group** is looking for a **graduate student** interested to **join our group** and work on **searches for new physics!**

(contact me at giaccone@fnal.gov or Raphael Cervantes at raphaelc@fnal.gov if you want to know more)