The CAST-RADES project progress: electrical tuning ideas and a new 30 sub-cavities axion detector design

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Motivation

Figure of merit:

$$F \sim g_{A\gamma}^{4} m_{A}^{2} B^{4} V^{2} T_{sys}^{-2} C^{4} Q$$

Set by the frequency.

To search for new axion masses freely with the same haloscope structure, **ferroelectric** and piezolectric technologies have been reviewed (techniques to make our axion haloscopes **electrically tunable**).

In order to **increase** cavity **volume**, and thus sensitivity, a new **30 sub-cavities** detector design provides a higher volume keeping the previous RADES frequency range, of ~8.4 GHz.

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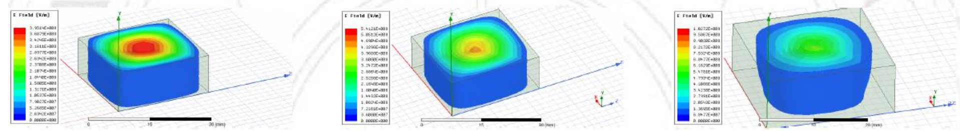
Methods

Tuning:

Simulations of a single RADES cavity loaded with a **dielectric post** in the middle provide poor form factors when permittivity increases.

ϵ_r	f_{r101} (GHz)	Q_{101} (2 K)	C_{101}
1 (or without post)	8.8851	45893	0.6571
2	8.4684	46706	0.6346
15	6.749	48087	0.3722



Our ferroelectric material requirements are:

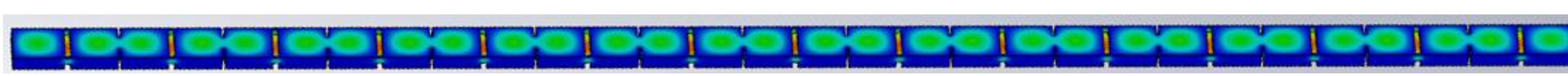
- Low **losses** (tanδ)
- **Cryogenic temperature** operation (1.8K)
- Ultra high **vacuum** (UHV) operation (10^{-9} mbar)
- Good **tunability**
- **Non-ferromagnetic**

$SrTiO_3$ meets these requirements. However, its **permittivity** is **extremely high**, so we need to find the best **position** inside the structure to avoid poor C.

*Also, a first 5 cavity prototype split into two halves has been manufactured and provides a tuning range of 700 MHz by varying the distance of the two halves.

New 30 sub-cavities design:

On the other hand, **CST** was used to do the 30-cav **simulations**, **optimization** of the dimensions and to plot the **electric field distribution** of each mode. This structure considerably increases the **sensitivity** of the sensor as compared to the previous RADES experiments.



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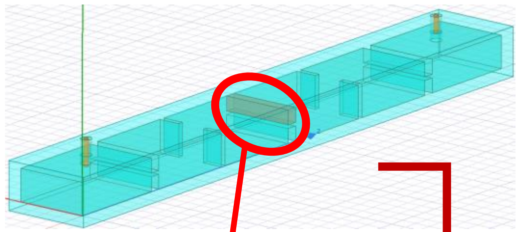
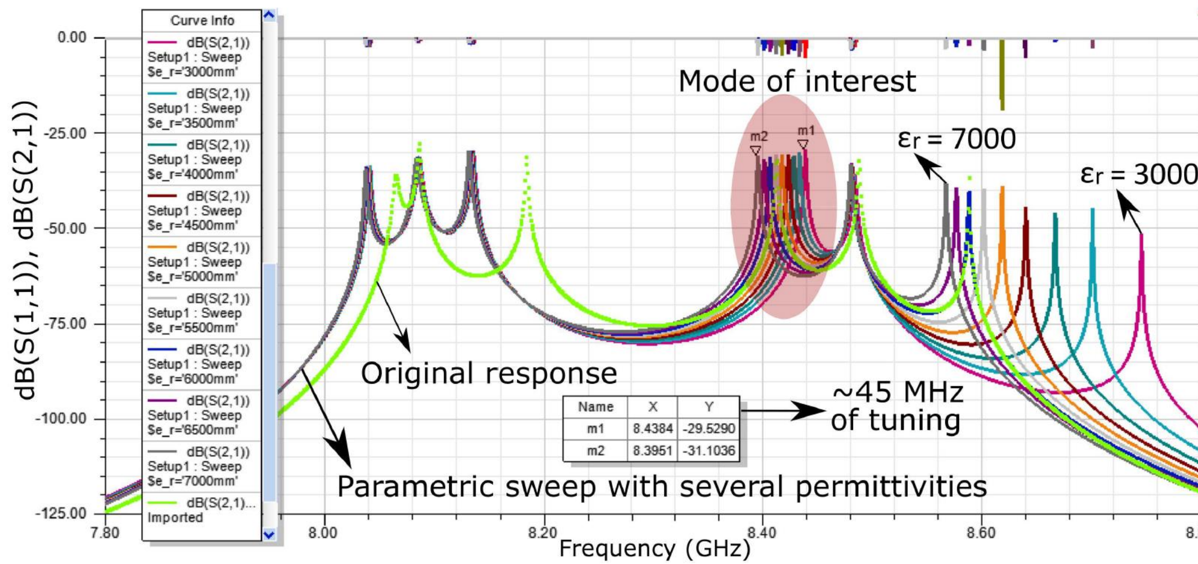
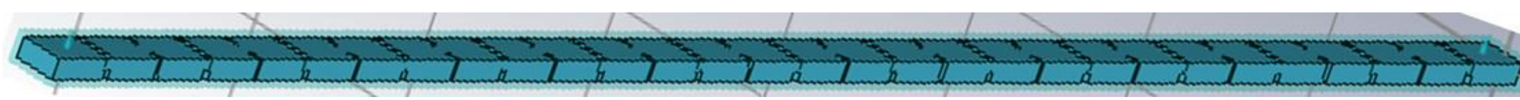
CERN CAST EXPERIMENT RAD.ES

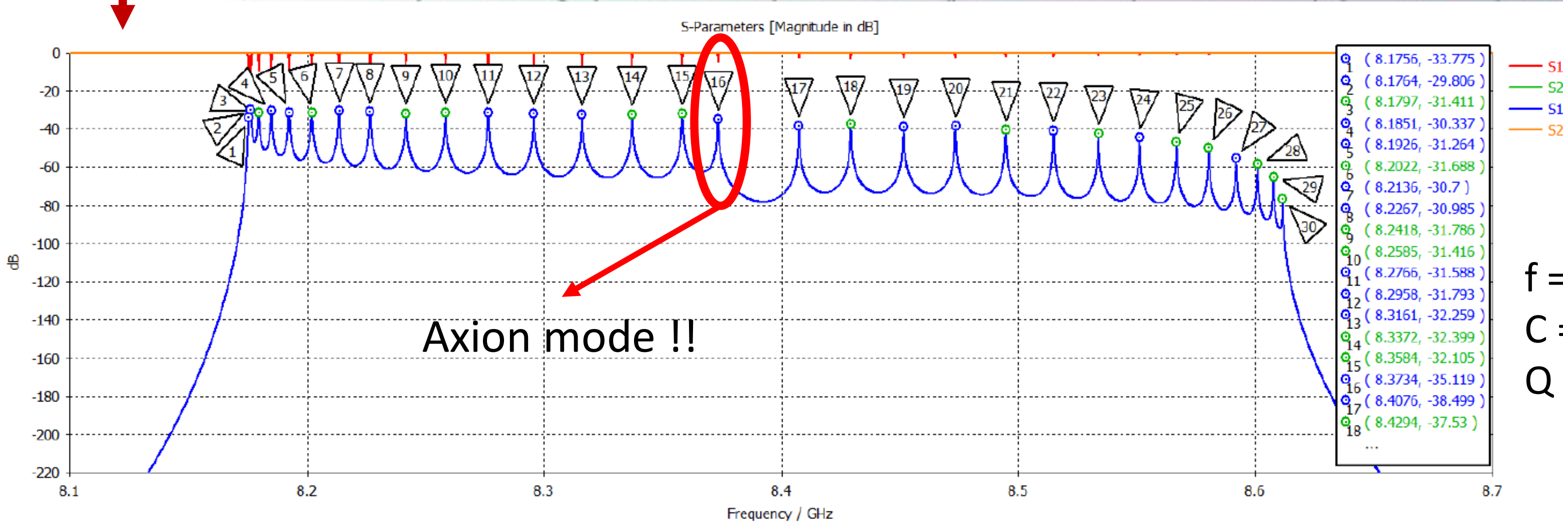
Results



$SrTiO_3$ ferroelectric







f = 8.37 GHz
C = 0.56
Q = 40320

Summary

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- Two ideas have been studied to have frequency control in the RADES structures

Ferroelectric at iris coupling (45 MHz in simulation varying the permittivity from 3000 to 7000)

Prototype **splited** into two halves (700 MHz of tuning range @300K varying manually the gap)

- We have designed and built a concrete implementation of a **30 sub-cavities structure**, that enjoys an optimized resonant mode at ~8.4 GHz.

- A **new data acquisition campaign** at the 9 Tesla CAST magnet (at CERN) is foreseen in **2019** with such structure.

- New cavity designs using more sub-cavities are under design to improve the properties of the cavity and to grow in volume. More detailed information from RADES structures can be found in:

A. Alvarez et al.
Axion searches with microwave filters: the RADES project.
JCAP, 040, May 2018.

Thank you for your attention

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