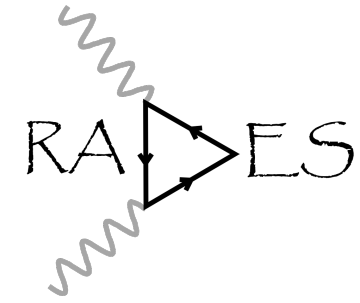




MAX-PLANCK-INSTITUT
FÜR PHYSIK



AXION SEARCHES WITH HTS COATED CAVITIES IN RADES

Cristian Cogollos

Max Planck Institute for Physics. Munich

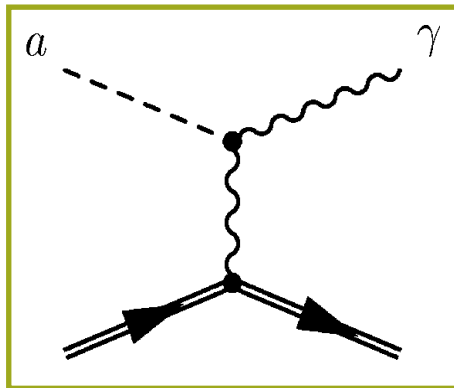
AXION HALOSCOPES



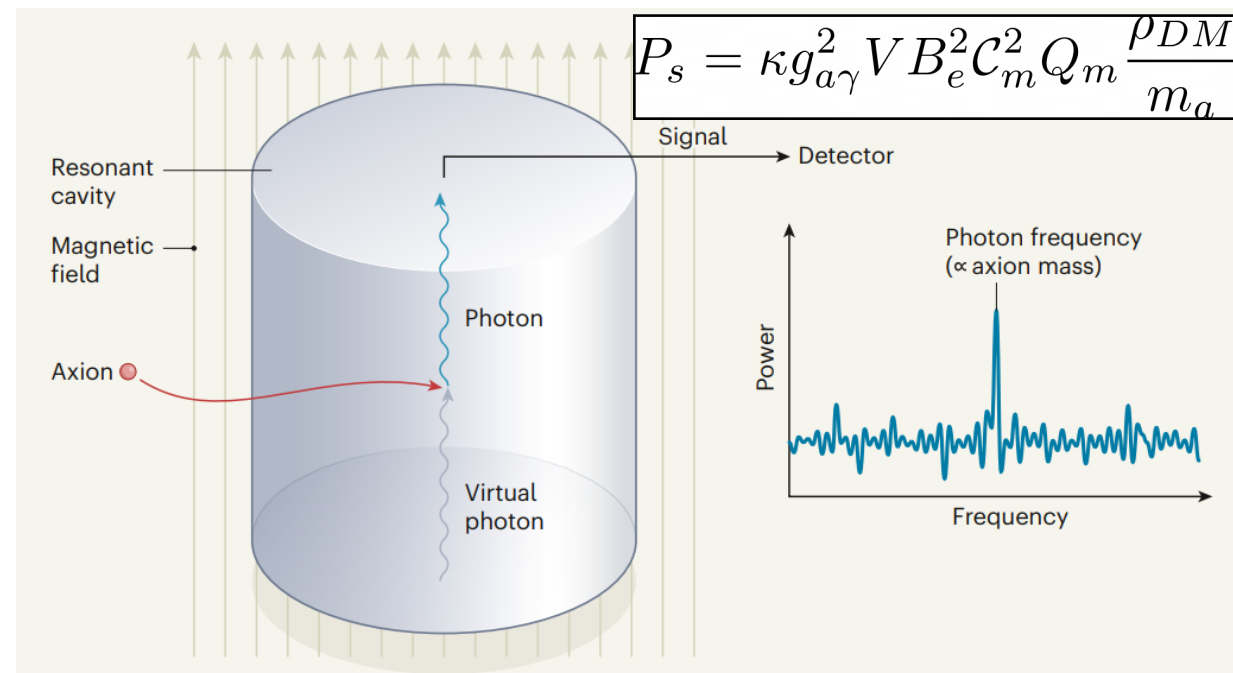
Axions are hypothetical pseudoscalar pseudoNambu-Goldstone bosons that could:

- Solve the strong CP problem of QCD
- Account for the dark matter content of the universe
- Mix with photons at low energies

Main detection strategy:
Conversion of axions into
photons under a strong
magnetic field



Haloscope approach to DM axion detection



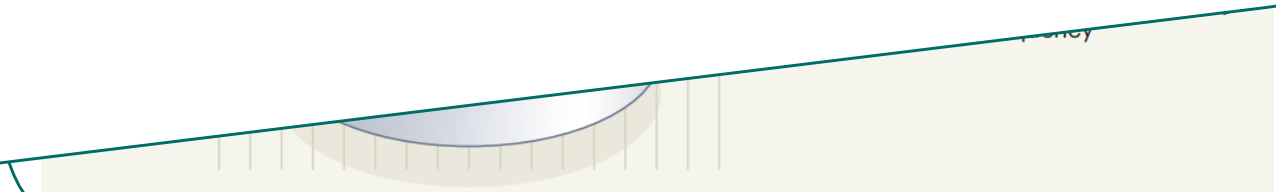
AXION HALOSCOPES

Axions are hypothetical pseudoscalar pseudoNambu-Goldstone bosons

- Solve the strong CP problem of QCD
- Axion

KONSTANTIN'S LAW:

ONE EXPLANATION OF THE
PRINCIPLES OF A HALOSCOPE
PER PATRAS WORKSHOP IS
MORE THAN ENOUGH*



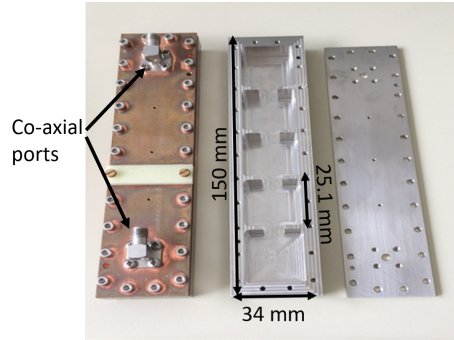
*You can refresh your memory checking my poster though

THE RADES COLLABORATION



Started as a haloscope experiment exploring the use of multi cavity structures for bigger detection volumes at higher frequencies.

Current Status of RADES Installation in CAST'



65th CAST collaboration meeting

September 26, 2017

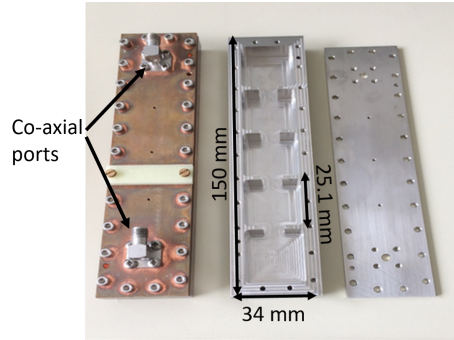
Antonio José Lozano Guerrero, Alejandro Álvarez Melcón, Benito Gimeno Martínez, Igor García Irastorza, Cristian Cogollos, Javier Redondo, Carlos Peña, Juan Daniel Gallego, Babette Döbrich and Alejandro Díaz Morcillo

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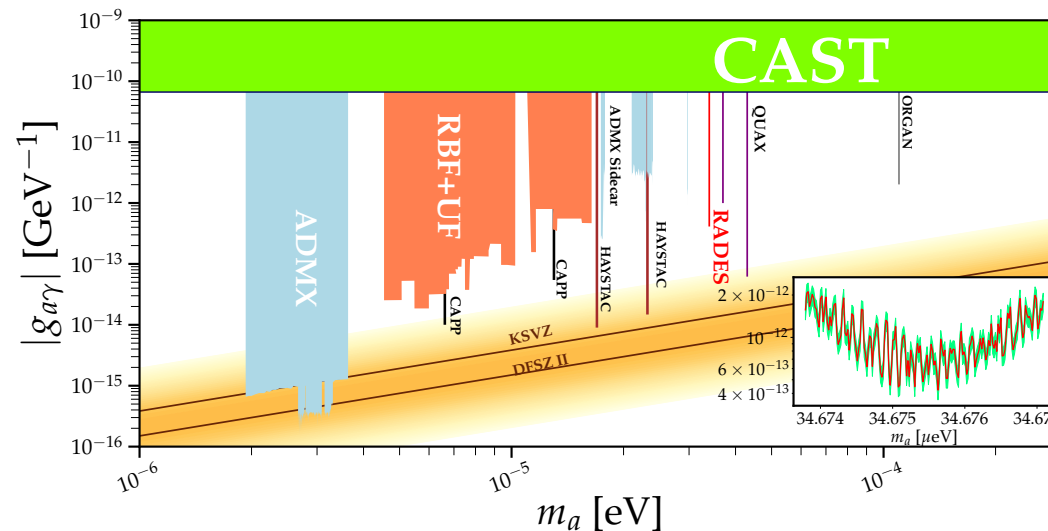
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Antonio José Lozano Guerrero, Alejandro Álvarez Melcón, Benito Gimeno Martínez, Igor García Irastorza, Cristian Cogollo, Javier Redondo, Carlos Peña, Juan Daniel Gallego, Babette Döbrich and Alejandro Díaz Morcillo



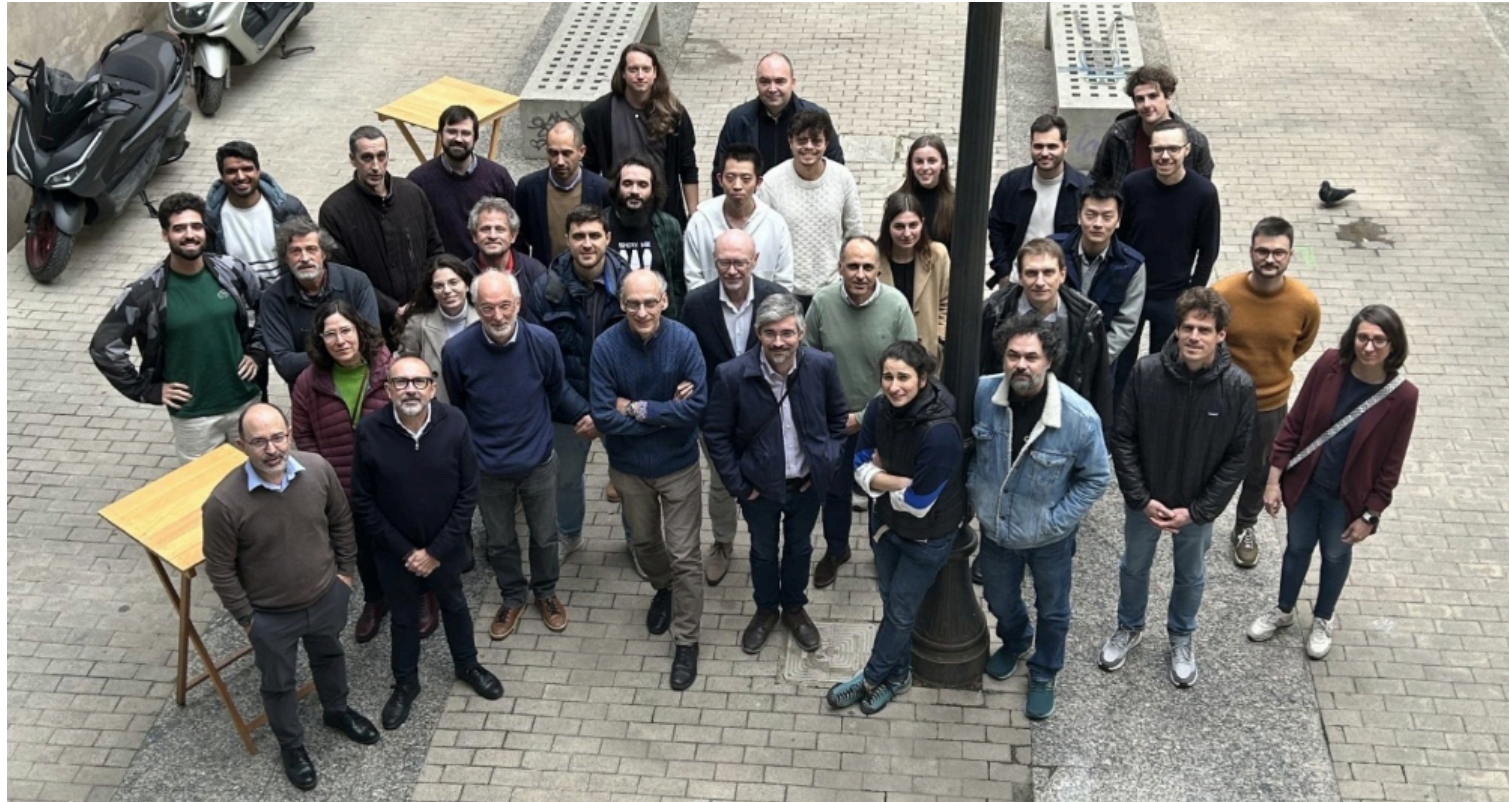
Figure 4.20 - Frustrated wannabe theorist student working on the experiment

A first run inside of the CAST magnet in 2018 served as a proof of principle and allowed us to extract exclusion limits for a mass of $34.67 \mu\text{eV}$



THE RADES COLLABORATION

Currently we are more than 30 collaborators from more than 10 different institutions working on cutting-edge technologies for high-frequency axion searches.



HTS COATED PROTOTYPE



Another approach for higher frequency searches in RADES

Increasing sensitivity of smaller cavities  Superconducting taped cavities

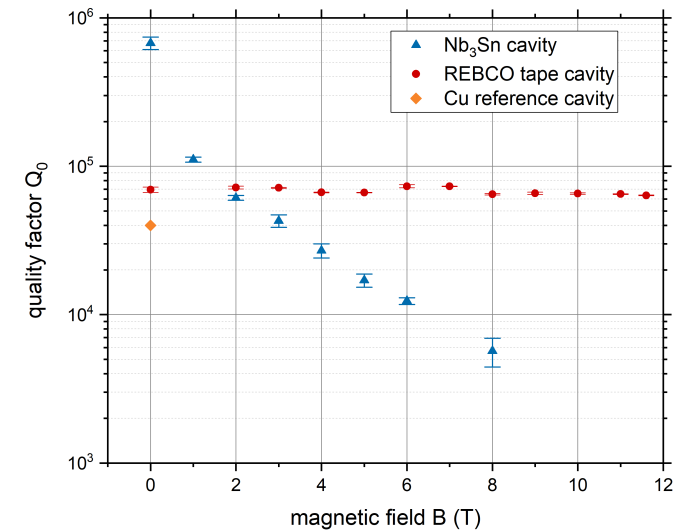
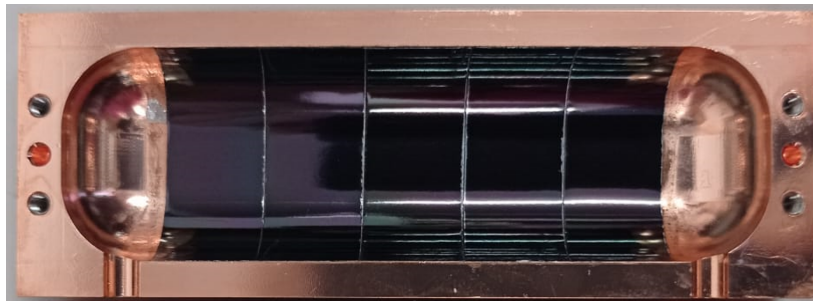
Thin Film (High Temperature) Superconducting Radiofrequency Cavities for the Search of Axion Dark Matter

J. Golm (CERN), S. Arguedas Cuendis (CERN), S. Calatroni (CERN), C. Cogollos (ICC, Barcelona U.), B. Döbrich (CERN) [Show All\(22\)](#)

Oct 4, 2021 IEEE Trans.Appl.Supercond. 32 (2022) 4, 1500605

[\[arxiv:2110.01296\]](#)

ReBCO tapes provided by THEVA used (Critical field over 100 T)



Q-Factor shows almost no degradation up to 12 T

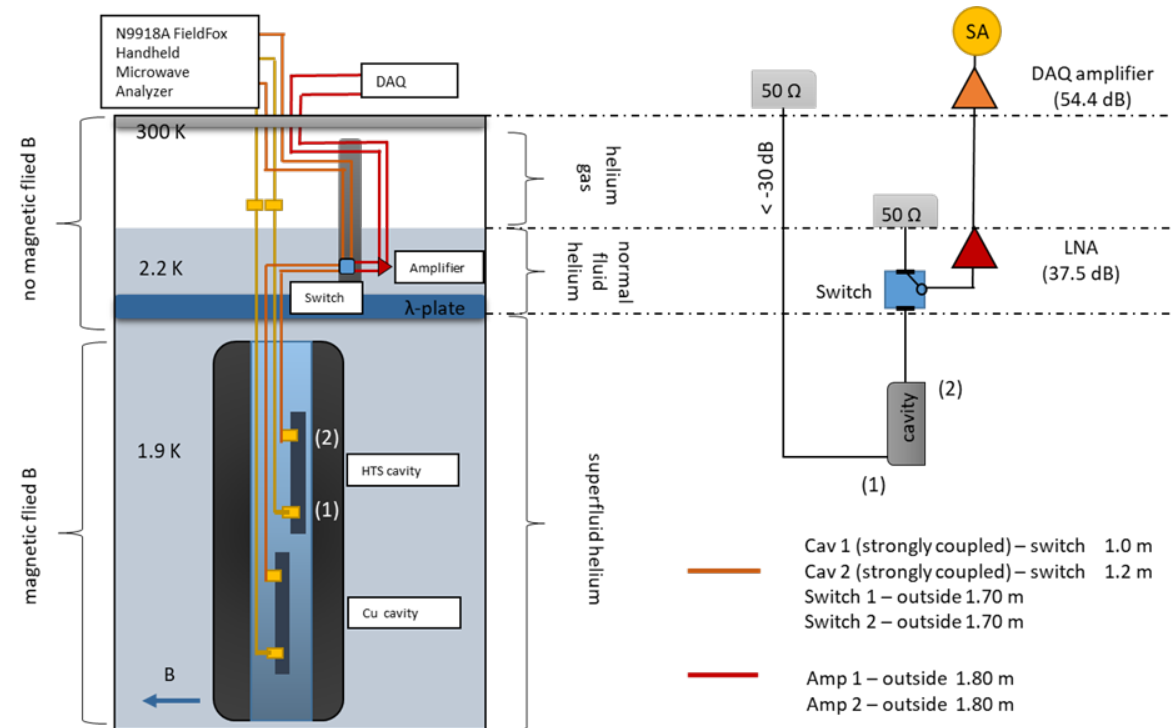
DATA TAKING 2021 AT CERN



In 2021 a data taking was performed at the SM18 magnet testing facility at CERN

Rather simple setup with 27 hours of axion data taking recorded

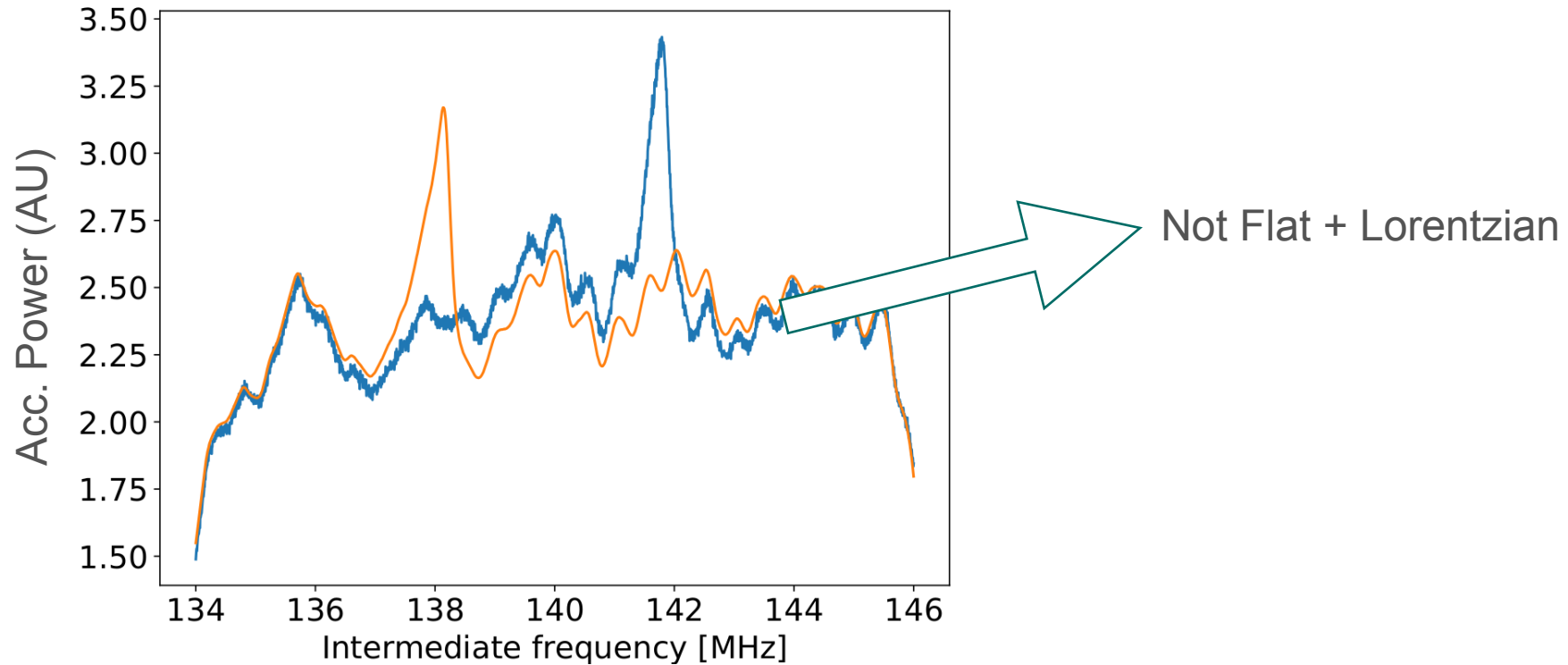
| Parameter | Symbol | Value |
|-----------------------|------------------|---------------------------------|
| Axion DM Density | ρ_a | 0.45 GeV cm^{-3} |
| Total cavity volume | V | $(0.0288 \pm 0.0002) \text{ L}$ |
| Magnetic field | B | $(11.7 \pm 0.1) \text{ T}$ |
| Loaded quality factor | Q_L | $(36\,656 \pm 387)$ |
| Coupling factor | β | (0.81 ± 0.01) |
| Form factor | C | (0.634 ± 0.001) |
| Cable attenuation | η | (0.85 ± 0.04) |
| Noise Temperature | T_{sys} | $(6.2 \pm 1.1) \text{ K}$ |



DATA ANALYSIS



However the data analysis was complicated due to a rather complex gain curve structure on the receiver system



A principal components analysis was performed in order to remove the
ease the effect of the DAQ noise structure

(Details in the poster)

DATA TAKING RESULTS

Last year we released the results for a first run with a high-temperature superconducting (HTS) coated cavity at the SM18 magnet testing facility at CERN

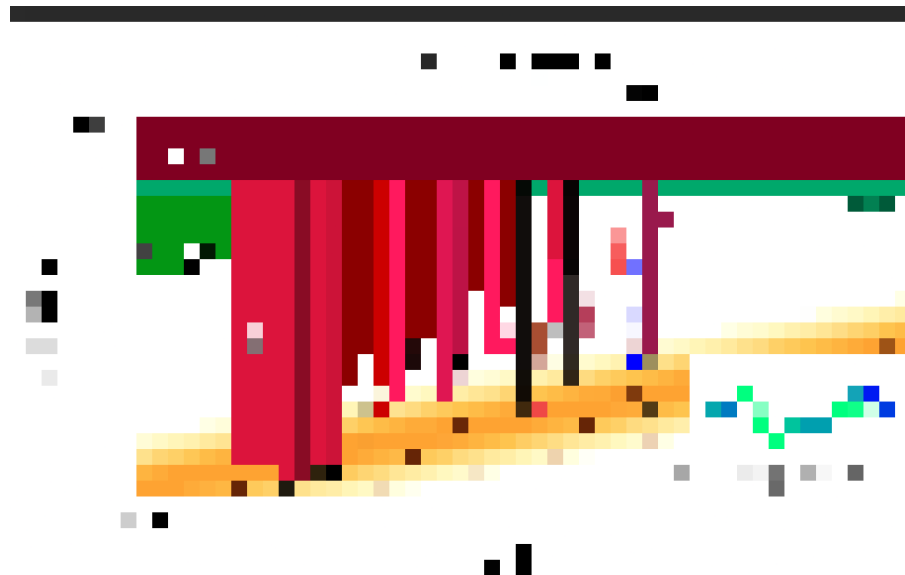
RADES axion search results with a high-temperature superconducting cavity in an 11.7 T magnet

S. Ahyoune (ICC, Barcelona U.), A. Álvarez Melcón (Cartagena Politecnica U.), S. Arguedas Cuendis (ICC, Barcelona U.), S. Calatroni (CERN), C. Cogollos (Garching, Max Planck Inst.) [Show All\(26\)](#)

Mar 12, 2024

JHEP 04 (2025) 113

[\[arxiv:2403.07790\]](#)



THANK YOU FOR YOUR TIME, AND I HOPE TO SEE YOU AT THE POSTER SESSION



Sergio Arguedas Cuendis

Main responsible for the analysis

Yours Truly

Jessica Golm

Responsible for the experimental setup and the data taking

Axion searches with HTS coated cavities in RADES

COGOLLOS Cristian, on behalf of the RADES Collaboration, *Max Planck Institute für Physik, Garching bei München

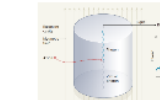
HALOSCOPES AT HIGHER MASSES

Haloscopes are intended to enhance the power measured after the conversion of DM waves into photons [1]

$$P_{\text{sig}} = \kappa_{\text{eff}}^2 \cdot V \cdot B_{\text{eff}}^2 \cdot Q_{\text{eff}} \cdot \frac{P_{\text{DM}}}{\rho_{\text{DM}}}$$

However, when targeting these higher masses the detection volume is compromised and so is the Q-factor. In order to reach the QCD-based novel technologies have to be implemented:

- Superconducting cavities • Smoothing the Q-factor
- Single photon detection • (Bosonic) DM signal to noise ratio



Figure">

THE RADES COLLABORATION

The RADES collaboration composed the implementation of multi cavity operations in haloscopes [2], culminating in our first successful data taking in 2019 by using the CAST magnet [3]. Currently we are more than 100 collaborators from more than 10 different institutions working on cutting-edge technologies to high-frequency axion searches.



FIRST RUN WITH HIGH-TEMPERATURE SUPERCONDUCTING (HTS) CAVITIES

In 2021 we performed a first data taking with a super cavity coated with Bi2212 in order to increase the quality factor (Q).

The quality factor of this Bi2212 coated cavity under the influence of a magnetic field was tested in the crystal at CERN [4].

This prototype showed a performance better than shiny copper and other superconducting cavities (Nb3Sn coated).

Figure">

RESULTS OF THE 2021 RUN

After analyzing a dataset of only 27 hours we obtained competitive results of higher masses than our previous search [5].

As a result we also tested the temperature of the liquid helium inside of the cavity in order to tune the resonant frequency.

A first look at the data indicates a successful run with a tuning of around 40 MHz, further analysis is ongoing.

Figure">

ELECTRONICS BACKGROUND AND PRINCIPAL COMPONENTS ANALYSIS (PCA)

The readout system presented a complex gain structure that required special characterization and calibration [6].

This allowed to remove the noise contribution to the electronic background without compromising the removal of structures that could mimic an axion signal.

The effect of the baseline removal was studied and tested against when compared to other effects such as applying a conventional Sensitivity Quality Index.

Figure">

SECOND RUN, NOVEMBER 2024

Last November we performed a second run in the same experimental facility with an improved data taking system and a new HTS coated cavity with a resonant frequency of 8.94 GHz.

As a result we also tested the temperature of the liquid helium inside of the cavity in order to tune the resonant frequency.

A first look at the data indicates a successful run with a tuning of around 40 MHz, further analysis is ongoing.

Figure">

OUTLOOK

The RADES Collaboration is advancing the study of promising new technologies for high-frequency axion searches, including the use of HTS coated cavities and the implementation of multi cavity operations.

A second run with an HTS coated cavity, representing different parts of the original setup was performed in 2024 and the data is currently being analyzed.

Step toward some upcoming results!

REFERENCES

[1] J. J. Heckman, Phys. Rev. D, **100**, 015011 (2019).

[2] J. J. Heckman et al., *Journal of Cosmology and Astroparticle Physics*, **2020**, 015 (2020).

[3] J. J. Heckman et al., *Journal of Cosmology and Astroparticle Physics*, **2020**, 015 (2020).

[4] J. J. Heckman et al., *Journal of Cosmology and Astroparticle Physics*, **2020**, 015 (2020).

[5] J. J. Heckman et al., *Journal of Cosmology and Astroparticle Physics*, **2020**, 015 (2020).

[6] J. J. Heckman et al., *Journal of Cosmology and Astroparticle Physics*, **2020**, 015 (2020).

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Peace, love, dark matter.