# Searching for Axion Dark Matter with DMRadio

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### Axions solve one of the biggest remaining problems in the Standard Model: the missing neutron electric dipole moment

Strong charge-parity (CP) problem

- We expect to see violation of charge parity symmetry in the strong interaction, but see no evidence of violation
- Neutron EDM expected to be  $\sim 10^{-10} \, \text{e} \cdot \text{cm}$
- Experiments sensitivities searching for nEDM are better than 10<sup>-26</sup> e·cm

 $\rightarrow$  fine tuning problem!

The axion is associated with the breaking of the Peccei-Quinn symmetry, introduced to solve the strong CP problem

The axion is a natural dark matter candidate



#### Axion parameter space covers ~10<sup>10</sup> mass range



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### DMRadio searches for axions below $1\,\mu\text{eV}$

DMRadio-GUT (PRD **106** (2022): 112003.)

- DFSZ 100 kHz 30 MHz
- Definitive search for GUT-scale QCD axions
- Next-generation detector that will require engagement from larger axion community





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- 5 kHz 5 MHz
- Testbed for technologies required for DMRadio-GUT





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DMRadio-m<sup>3</sup> (PRD **106** (2022): 103008, arXiv:2302.14084)



### **DMRadio Collaboration**

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#### Probing QCD axions through electromagnetism

- Axion field converts to an oscillating electromagnetic signal in the presence of a magnetic field (Primakoff effect)
- Enhance signal with a tunable resonator

Proposal: Sikivie (1983) v > 300 MHz Cavity-based searches (ADMX, HAYSTAC,...)



Proposal: Cabrera, Thomas (2010) v < 300 MHz Lumped element searches (DMRadio,...)



#### DMRadio detection mechanism for low-mass axions





Toroidal magnet with field  $B_0$  creates current  $J_{eff}$ 

J<sub>eff</sub>induces magnetic field B<sub>ind</sub> Bind Jind

> B<sub>ind</sub> induces J<sub>ind</sub> which is enhanced by an LC resonator and picked up by a sensor

## DMRadio-50L cryostat cools a toroidal magnet, an LC resonator, sensor, and superconducting shielding



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## To cool detector components, DMRadio-50L uses a horizontal dilution refrigerator connected to a large cryostat



Bluefors LH400 with cold fingers on still and MXC plates



Four9 Design large cryostat with PT425

# To cool detector components, DMRadio-50L uses a horizontal dilution refrigerator connected to a large cryostat



Vertical supports

**Flexible connections** 

Cold finger connection:

- Thermally conductive in the horizontal direction
- Mechanically flexible in the horizontal direction
- Mechanically supportive in the vertical direction

#### DMRadio-50L magnet is constructed, to be cryo tested

Superconducting persistent magnet

- 1 T peak field
- Aluminum mandrel
- Two mandrel halves connected by insulating spacers
- Superconducting Systems, Inc (now Imris) in MA



### DMRadio-50L high quality factor LC resonator

DMRadio-50L resonator

Inductor in the middle



Resonator prototype

- Achieved Q ~ 2 million at ~250 kHz
- Tunability to be implemented



Prototype capacitor: Al1100 parallel plates

Prototype inductor: NbTi wire on sapphire rods 17











### Conclusions

- Axions are well-motivated dark matter candidate with masses reaching as low as the GUT scale
- The DMRadio program is searching for axions < 1  $\mu$ eV
- DMRadio-GUT is a next-generation axion detector that could discover new physics at the GUT scale



DMRadio-GUT sketch



DMRadio-50L cryostat

- DMRadio-50L is in the process of commissioning
- DMRadio-50L will search for low-mass axions with unprecedented sensitivity and be a testbed for technologies required for DMRadio-GUT

#### Thanks for listening!