Analysis of ABRACADABRA Data

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subMIT workshop

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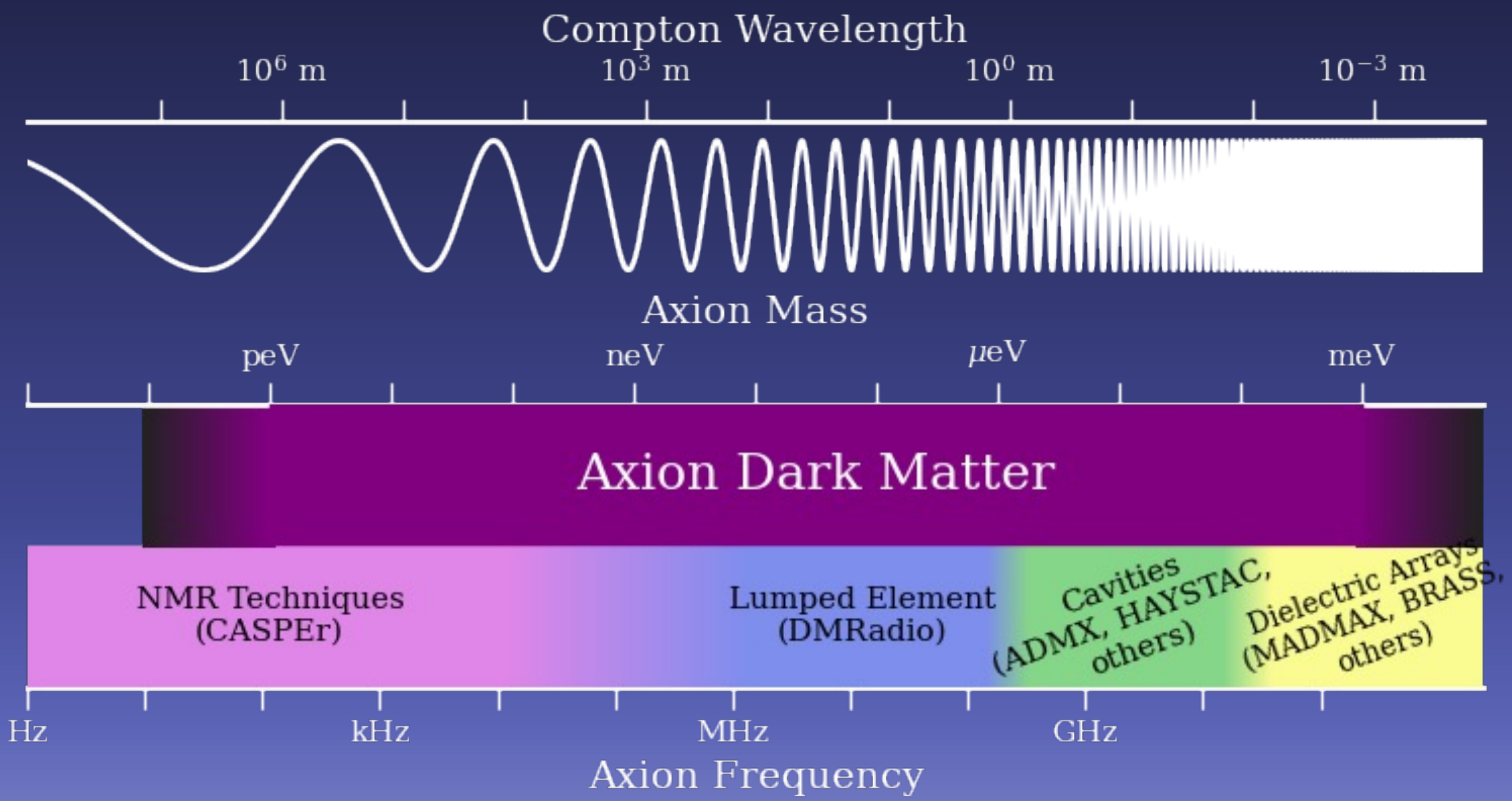
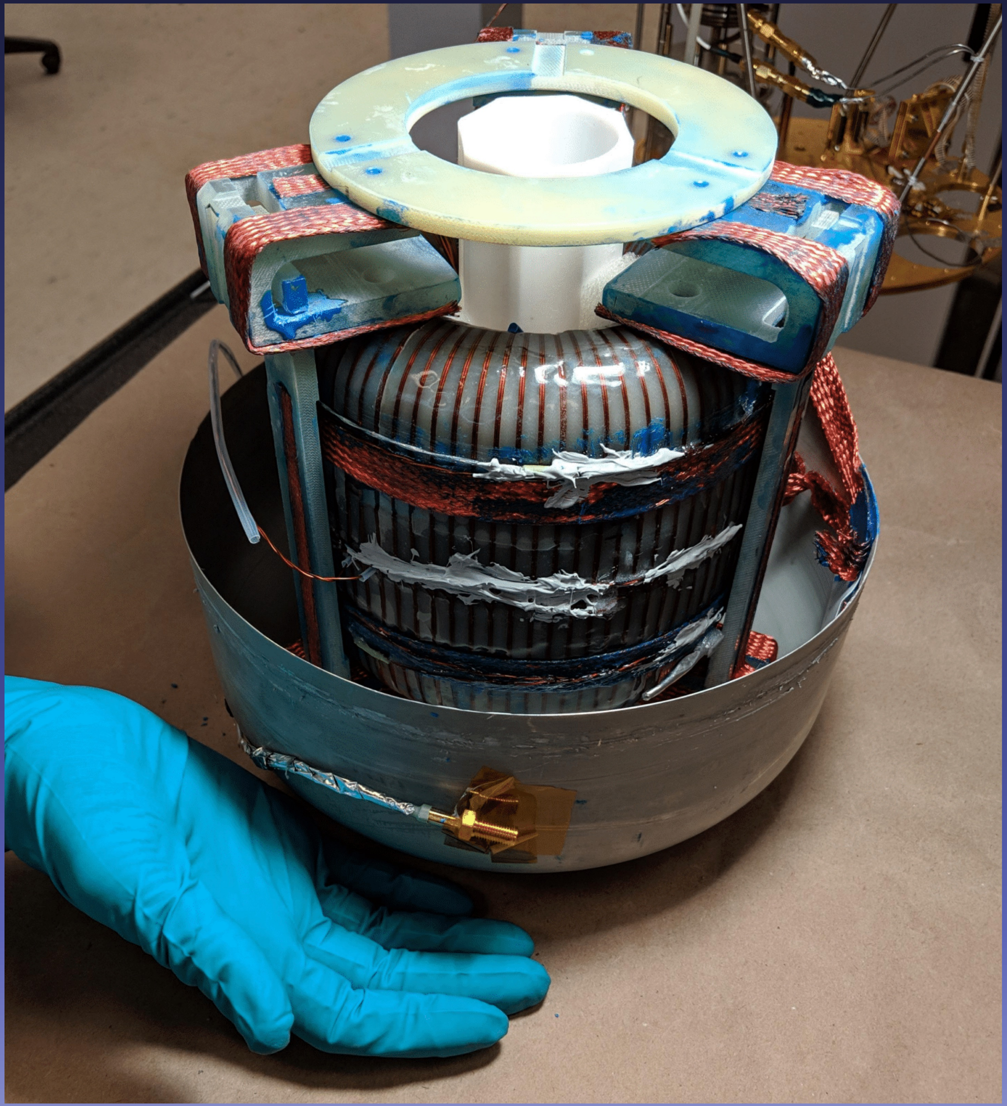
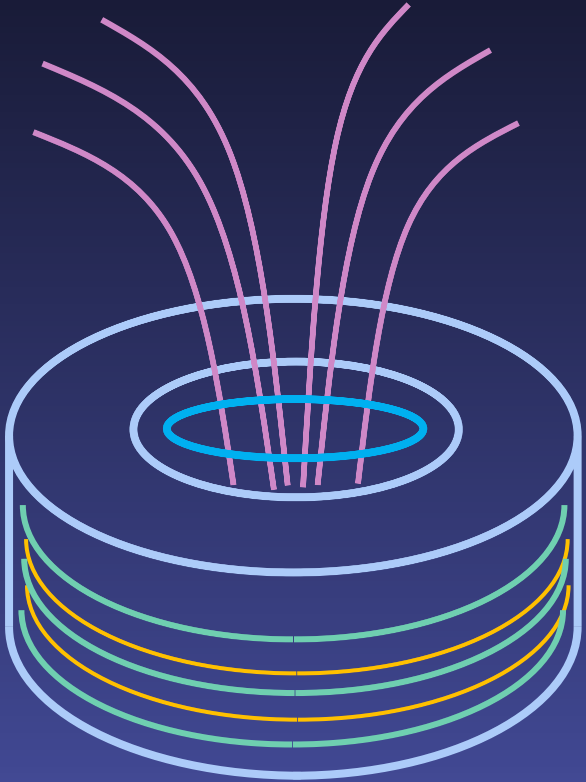
Axion Detection: Axion Mass and Frequency



ABRACADABRA



Pickup structure



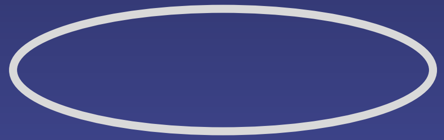
Induced B-field

1 T B-field

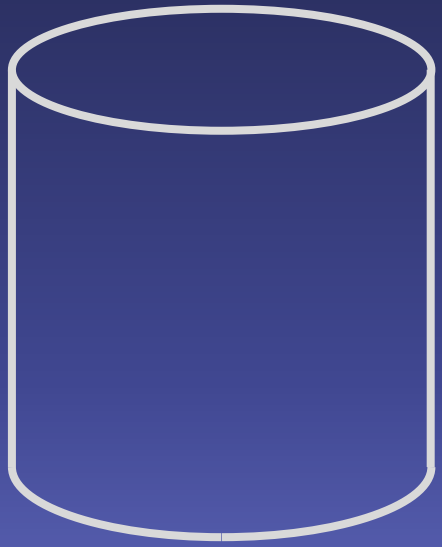
$$J_{eff} = g_{a\gamma\gamma}\sqrt{\rho_{DM}}\cos(m_a t)B$$

ABRACADABRA pickups

Run 1



Run 2 & 3



Greater sensitivity to
axion signal and noise

ABRACADABRA-10cm Data Overview

- Data taken at MIT using a two-channel Alazar digitizer card (we use one channel for axion runs)
- Sampling at 10 MS/s, averaged down and saved in discrete Fourier transforms as PSDs
- Data taking, averaging and discreate Fourier transforms done on local computer and saved on local computer

10.1103/PhysRevD.99.052012
10.1103/PhysRevLett.127.081801

Run History and Data Storage

Run #	Data size	Current data location*	Analysis location
Run 1 (axion data) DOI: 10.1103/PhysRevLett.122.121802	~ 4 T	U Michigan Cluster	U Michigan Cluster
Run 2 (axion data)	~ 4 T	U Michigan Cluster and Berkeley Cluster	Berkeley Cluster
Run 3 (axion data) DOI: 10.1103/PhysRevLett.127.081801	4.0 T	Berkeley Cluster and MIT cluster	Berkeley Cluster
Run 4 (noise data)	3.0 T	MIT cluster	Local computer + MIT cluster
Run 5 (noise data)	3.2 T	Local computer	Local computer + MIT cluster

*With the exception of Run 5, all runs are also backed up on external hard drives

Axion Analysis

Analysis for runs 1-3 were done by Joshua Foster

Log-likelihood ratio test of signal and null models was preformed

$$\mathcal{L}(\mathbf{d}_{m_a}|A,\mathbf{b}) = \prod_{j=1}^{\mathcal{N}} \prod_{k=k_i(m_a)}^{k_f(m_a)} P(\bar{\mathcal{F}}_{j,k}; N_{\mathrm{avg},j}, \lambda_{j,k})$$

$$\mathrm{TS}(m_a) = 2\ln\left[\frac{\mathcal{L}(\mathbf{d}_{m_a}|\hat{A},\hat{\mathbf{b}})}{\mathcal{L}(\mathbf{d}_{m_a}|A=0,\hat{\mathbf{b}}_{A=0})}\right]$$

5σ discovery condition is based on a TS threshold

Solved over ~ 13 million mass points for Run 1 and 11.1 million mass points for Run 3

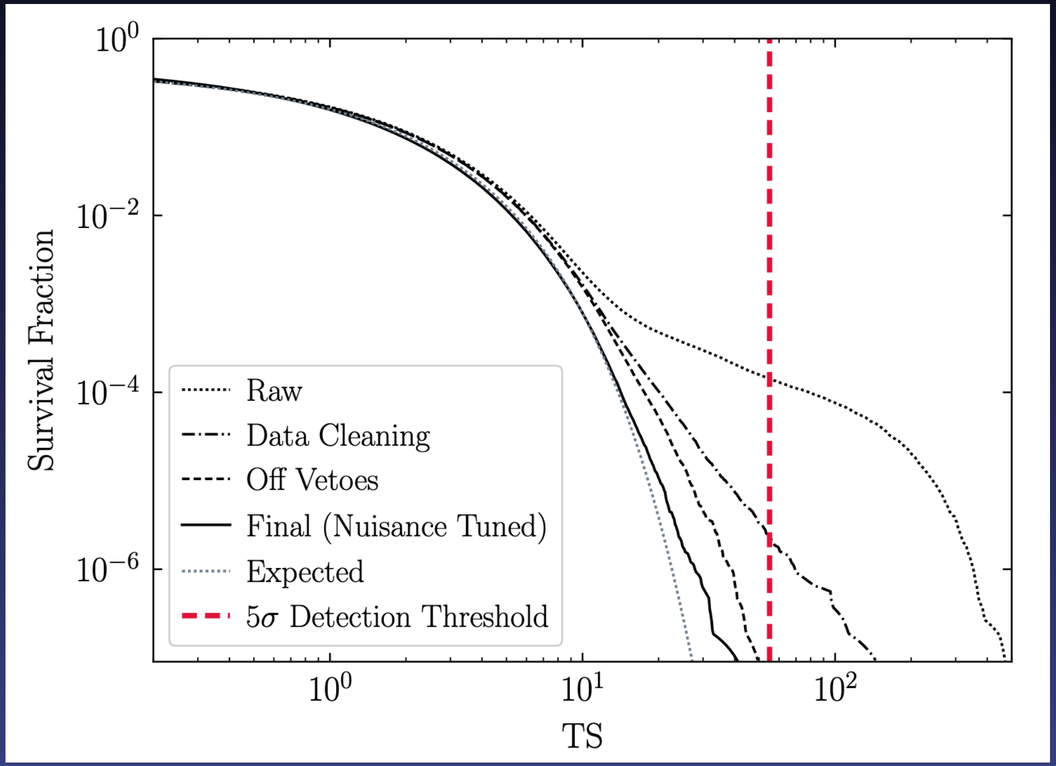
Done in python

10.1103/PhysRevD.99.052012
10.1103/PhysRevLett.127.081801

Axion Analysis

Additional evaluations:

- Data cleaning
  - Removing narrow and time-dependent signals
- Magnet off vetoes
- Removal of noisy data
- Recovering an injected signal



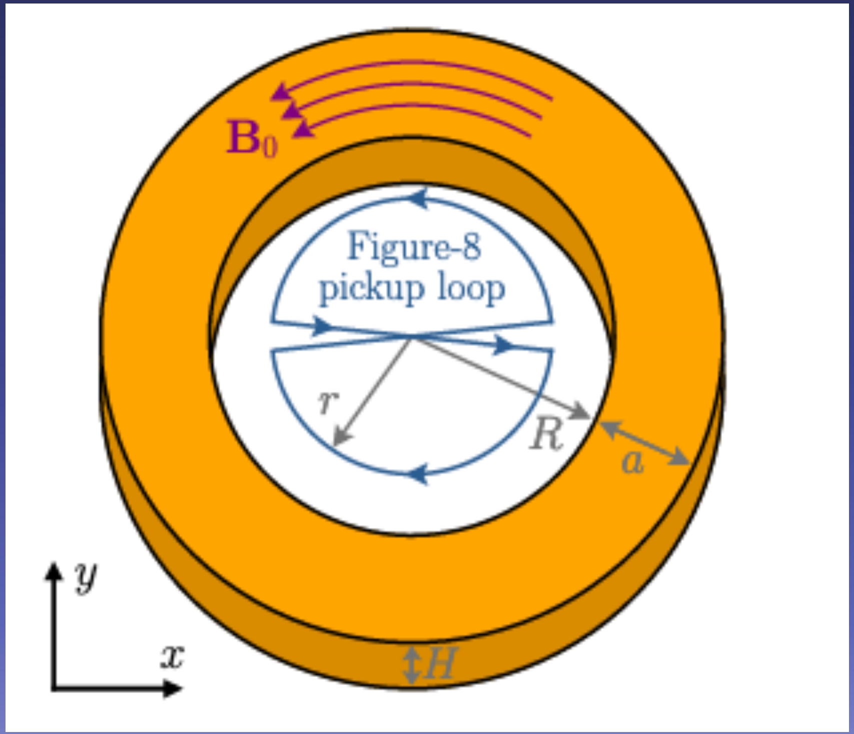
Run 3 test statistic survival function*

10.1103/PhysRevD.99.052012
*10.1103/PhysRevLett.127.081801

ABRA + Gravity Wave Detection

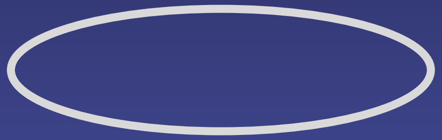
High-frequency gravitation wave search with a figure eight pickup structure (arXiv:2202.00695v)

- Run in conjunction with a standard axion detection run
- Construction complete, data taking beginning in next couple of weeks

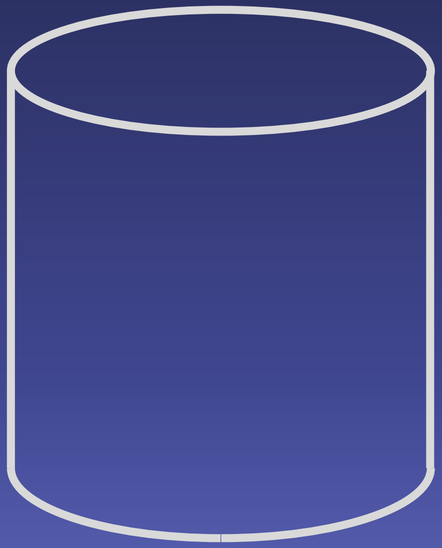


ABRACADABRA pickups

Run 1

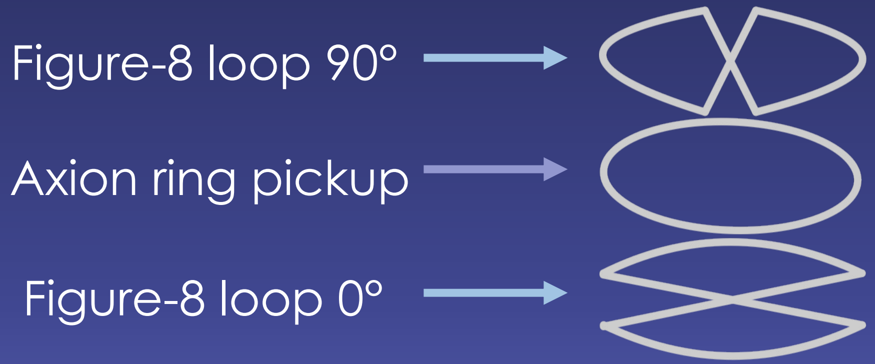


Runs 2 - 5



Greater sensitivity to axion signal and noise

Run 6



Current Run: Axions and Gravitational Waves

Reading out two channels in two different runs

→ Four times as much data ~ 16 T

Data will be collected on the lab computer then transferred once data run is completed

1. Axion + signal gravitational wave detector
   - ~ three weeks of data
2. Two gravitational wave detectors
   - ~ six weeks of data

Current Run: Axions and Gravitational Waves

Two different analyses:

1. Standard axion analysis
   - Same as Run 1
2. Gravitational wave analysis
   - Analyzing possible detectable signals over galactic coordinates (astropy and other standard packages)

Expected Computational Needs

Storage:

- All data: 11 T (old data not including Runs 1 and 2) + 32 T (new data) = 43 T

CPU hours for Run 6:

- ~10 CPU years for O(weeks) worth of data

General use:

- Viewing data with jupyter notebook, plotting spectra + simple calculations all in python