ADMX Status Update

Ana Malagón

University of Washington, ADMX Collaboration

May 23, 2015/CIPANP Vail, CO

Outline

1. The Strong CP Problem
2. Axion as Dark Matter
3. The Experiment
4. Upgrades for Gen2
5. Research In Progress

Strong CP Problem

$$\mathcal{L}_{QCD} = \frac{\theta}{32\pi} G\tilde{G}$$

1. θ exactly cancels CP violating phase from CKM matrix so that CP-violating observable $\bar{\theta} < 10^{-10}$ (limit from null observations of neutron EDM).
2. Why is that?

Peccei-Quinn Mechanism

1. Introduce a new global chiral symmetry: $U(1)_{PQ}$
2. The Goldstone boson of the broken symmetry is a massless axion: $a(x)$.
3. Anomalies of the symmetry with QCD introduce a potential for $a(x)$ (and therefore a small mass, $m_a \propto f_a^{-1}$):

$$\frac{a(x)}{f_a} G\tilde{G}$$

4. The minimum value of the total potential from $\bar{\theta}$ and $a(x)$ gives $\langle a(x)/f_a - \bar{\theta} \rangle = 0$.

This is not the only solution to the strong CP problem, but provides a testable low energy observable: the axion.

Axion as Dark Matter

1. The effects of the potential
$$\frac{a(x)}{f_a} G\tilde{G}$$
only become important after energy scales are less than Λ_{QCD}.
2. Therefore at higher energies the initial value of $a(x)$ can be "misaligned" from $\langle a(x) \rangle = \bar{\theta}$.
3. This initial misalignment of the field provides a primordial energy density of axions.
4. If this primordial population is feebly interacting, stable, and cold, it could be dark matter.

Dark Matter Axion: where is it?

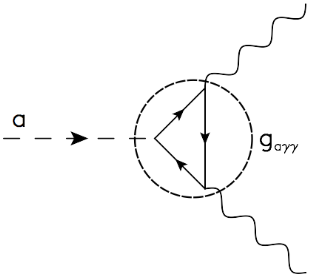
Between 1 μeV[1] and 1 meV, roughly.

corresponds to 10^9 GeV $\leq f_a \leq 10^{12}$ GeV.

Axion coupling to two photons $g_{a\gamma\gamma}$ predicted to be:

$$\text{KSVZ: } |g_{a\gamma\gamma}| = 0.002/f_a \text{ GeV}^{-1}$$

$$\text{DFSZ: } |g_{a\gamma\gamma}| = 0.008/f_a \text{ GeV}^{-1}$$



For $m_a = 10^{-5}$ eV dark matter axion:

Number Density: 10^{16}/Liter

DeBroglie Coherence Length: 100 m

Energy Resolution ΔE_a : $10^{-6} m_a$

Frequency of Corresponding Photon: 2.4 GHz

[1] this is a very squishy bound

Experimental Handles

Microwave Cavity Searches: $g_{a\gamma\gamma}^2$

ADMX
ADMX-HF
KAIST

Photon Regeneration: $g_{a\gamma\gamma}^4$

ALPs-II

Solar Axion Searches: $g_{a\gamma\gamma}^4$

CAST

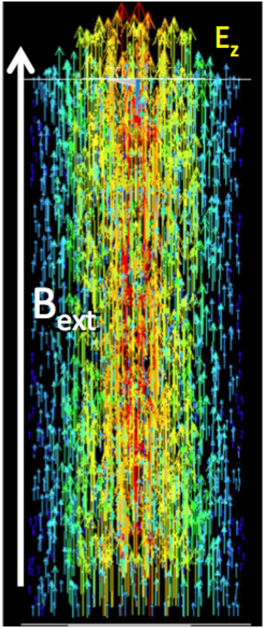
Macroscopic Spin Forces: $g_S g_P$

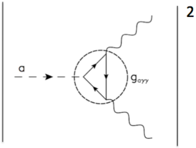
Eot-Wash (torsion pendulum)
ARIADNE (polarized He^3)

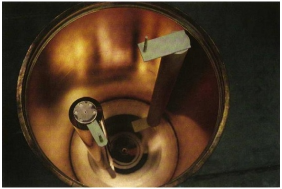
Oscillating EDMs: g_{aNN}^2

CASPER

Signal



Rate $\propto$ 



$$\mathcal{L}_I = -\frac{1}{4} g_{a\gamma\gamma} a F \tilde{F} = g_{a\gamma\gamma} a \vec{E} \cdot \vec{B}$$

$$\text{Signal Power} = g_{a\gamma\gamma}^2 a^2 [B_{\text{ext}}^2 V] C Q$$

$g_{a\gamma\gamma}$ - coupling constant $\quad B_{ext}$ - external magnetic field

$m_a a^2 = \rho_a$ local dark matter energy density $\quad V$ - volume

C $= \mathcal{O}(1)$ form factor $\quad Q$ - quality factor

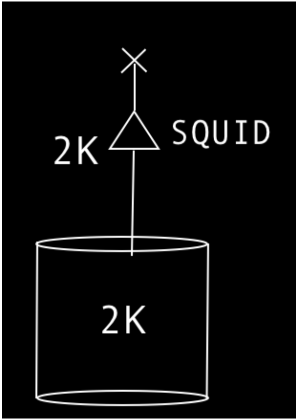
Noise

Background = Johnson Noise of Cavity + Noise from Electronics

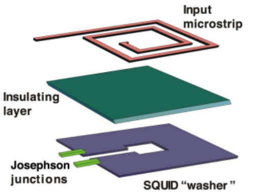
$$\text{System Temperature} = T_{cavity} + T_{amp}$$
$$\text{Statistical Fluctuations: } \Delta T = \frac{T_{system}}{\sqrt{\tau BW_{\mathrm{a}}}}$$

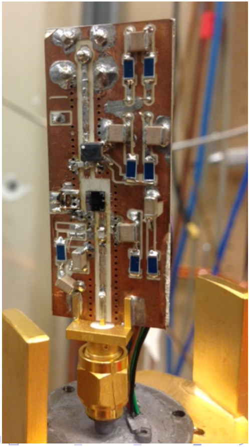
→ To reach KSVZ sensitivity @ averaging times of $\tau = 100$ s, stepped by $\mathcal{O}(1\%)$ of cavityBW.

2014 run temperatures

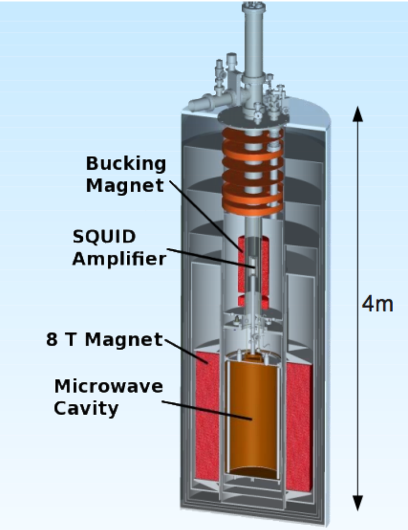


microstrip squid amplifier



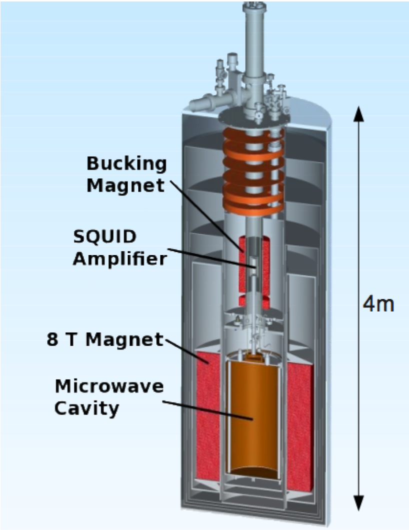


Magnet

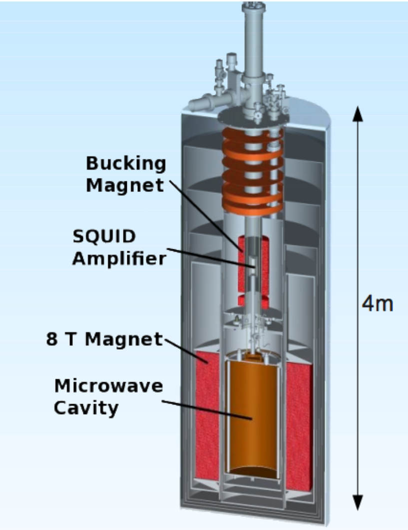

Bucking
Magnet
SQUID
Amplifier
8 T Magnet
Microwave
Cavity
4m


N

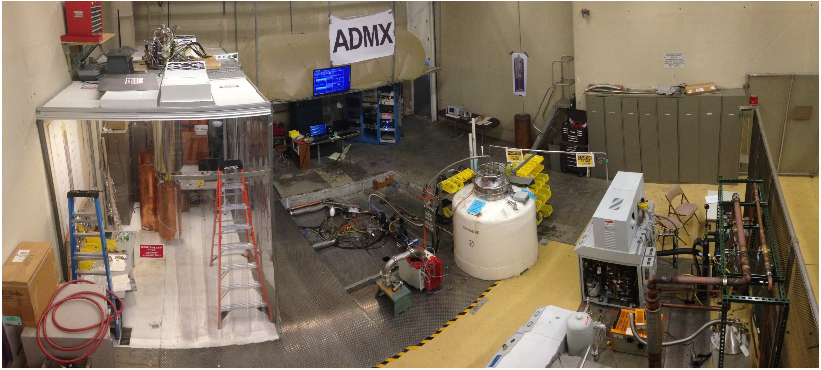
Insert


Bucking
Magnet
SQUID
Amplifier
8 T Magnet
Microwave
Cavity
4m

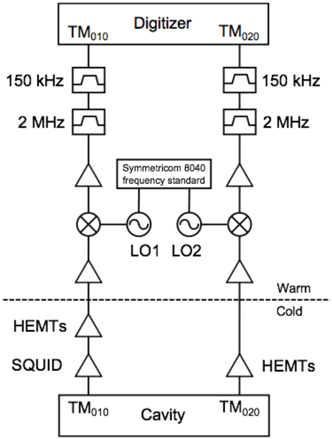
Insert

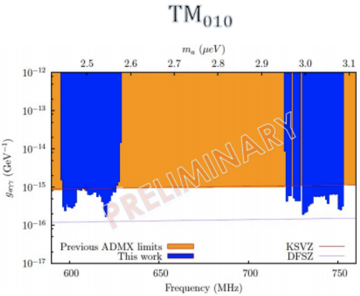

Bucking Magnet
SQUID Amplifier
8 T Magnet
Microwave Cavity
4m

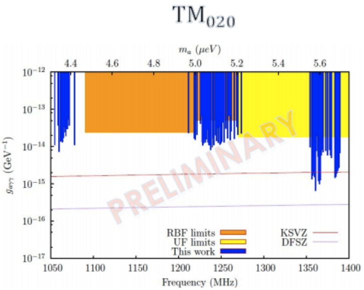
Experimental Site



Results from 2014

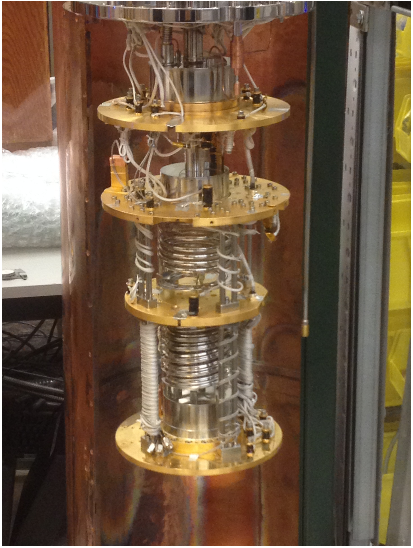






Upgrades for Gen2

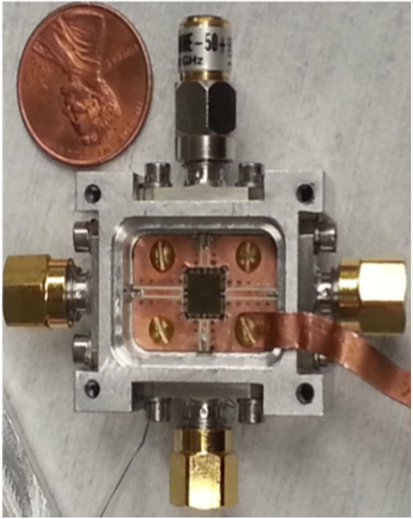
Dilution Refrigerator: $T_{system} \approx 200$ mK.



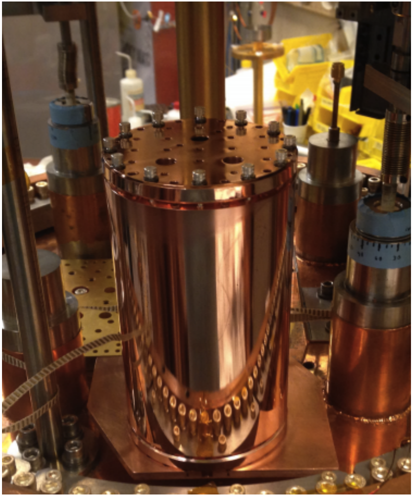
- Arrived March 30th.
- Plan to turn on to begin tests of <Kelvin temps in two weeks.

Upgrades for Gen2

JPA on second channel.

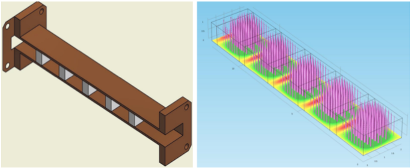


Sidecar @ 3.9+ GHz, will be able to reach $g \simeq 10^{-14}\ \mathrm{GeV}^{-1}$

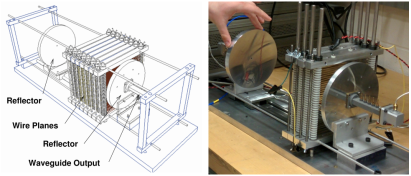


Research in Progress

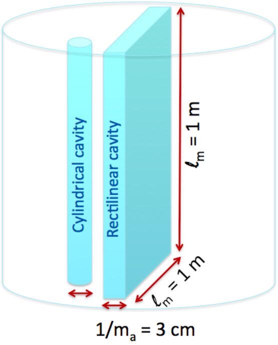
dielectric plates in waveguide



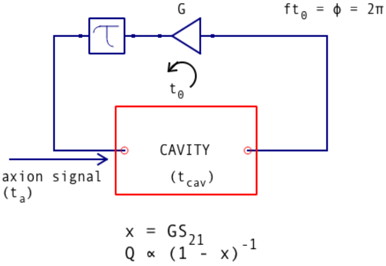
sinusoidal magnetic field



rectangular cavities

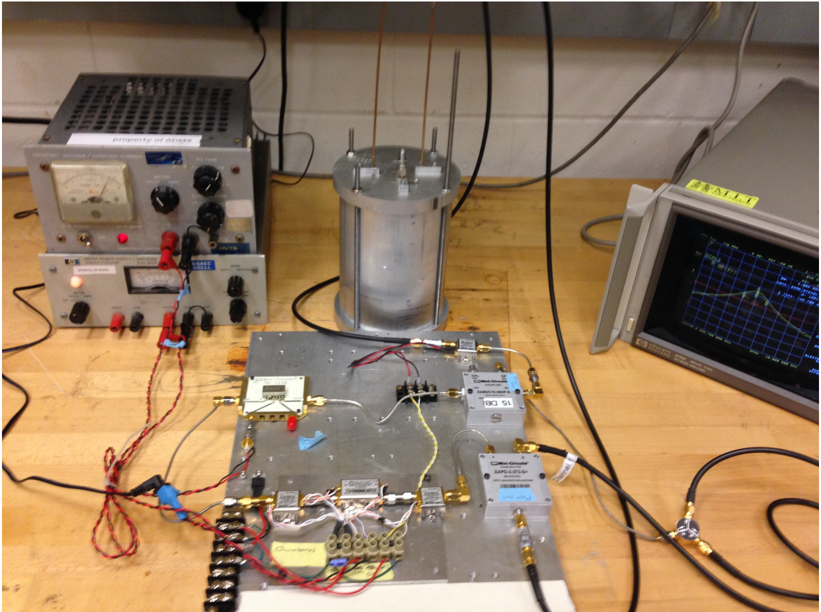


feedback



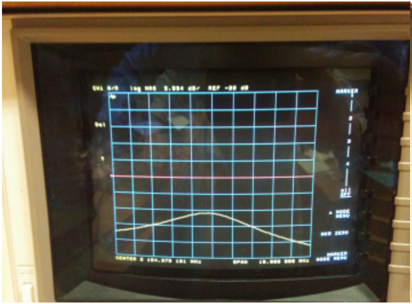
Initial Setup

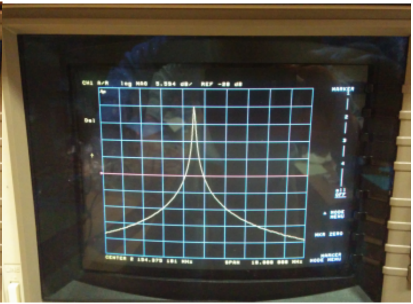
feedback using amplifiers, variable attenuator, and phase shifter



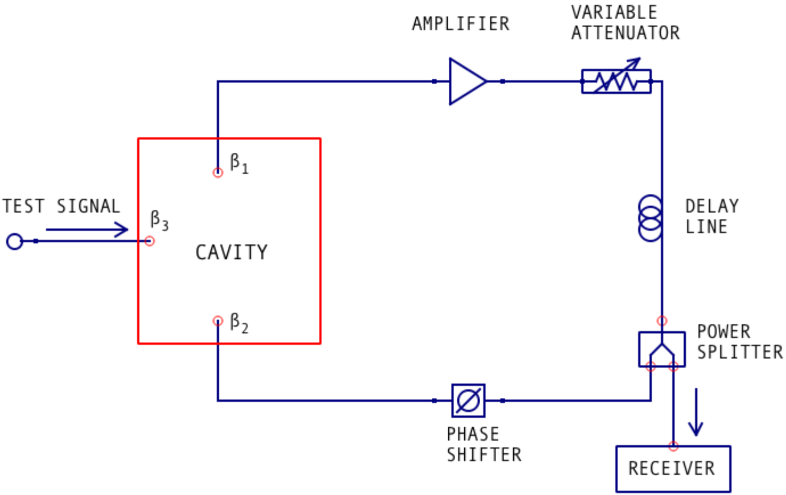
Q Enhancement

adjusting variable attenuator allows Q to range from 1000 to 9000 before oscillations begin



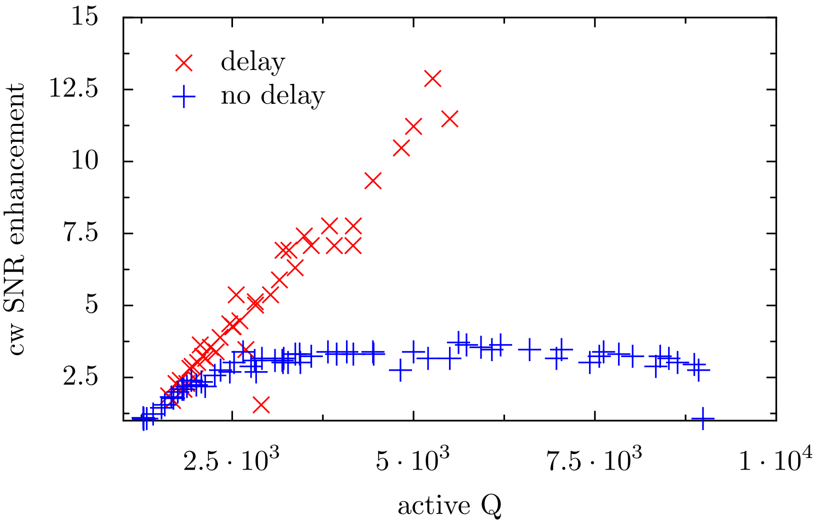


Schematic



AMPLIFIER
VARIABLE ATTENUATOR
TEST SIGNAL
β_1
β_3
CAVITY
β_2
DELAY LINE
POWER SPLITTER
PHASE SHIFTER
RECEIVER

Results



need to understand thermal noise in circuit and effect of coherence times, phase.

People

Fermilab Aaron Chou
LBNL Gianpaolo Carosi
University of Washington Leslie Rosenberg Gray Rybka Christian Boutan James Sloan Cliff Plesha Hannah LeTourneau Rich Ottens Kunal Patel Kiva Ramundo Jacob Herr Xavier Frost Ana Malagon
University of Florida David Tanner Neal Sullivan Ian Stern Nicole Crisosto Joe Gleason
Berkeley Irfan Siddiqi Karl van Bibber John Clarke Sean O'Kelley
Sheffield U Edward Daw
NRAO Richard Bradley

Previous Members Michael Hotz Andrew Wagner Dmitry Lyapustin Jeffrey Hoskins Leanne

Duffy Steve Asztalos Darin Kinion Danny Yu Edward Daw Christian Hagmann

Fin