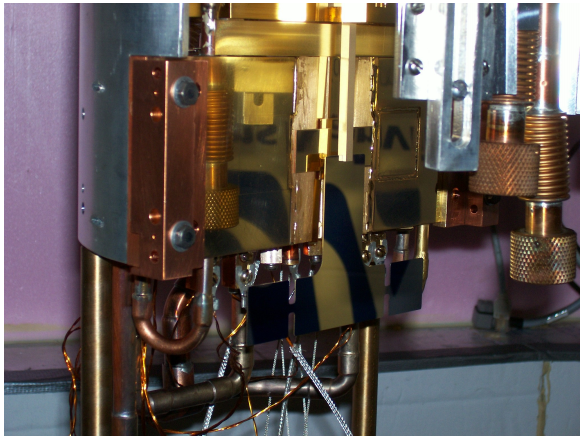
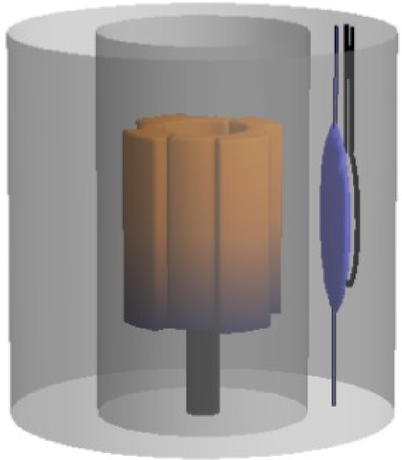
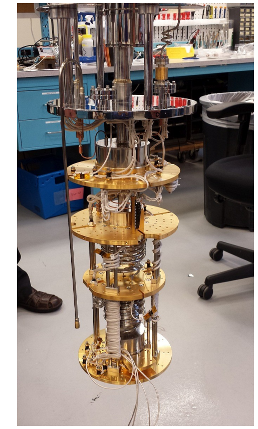


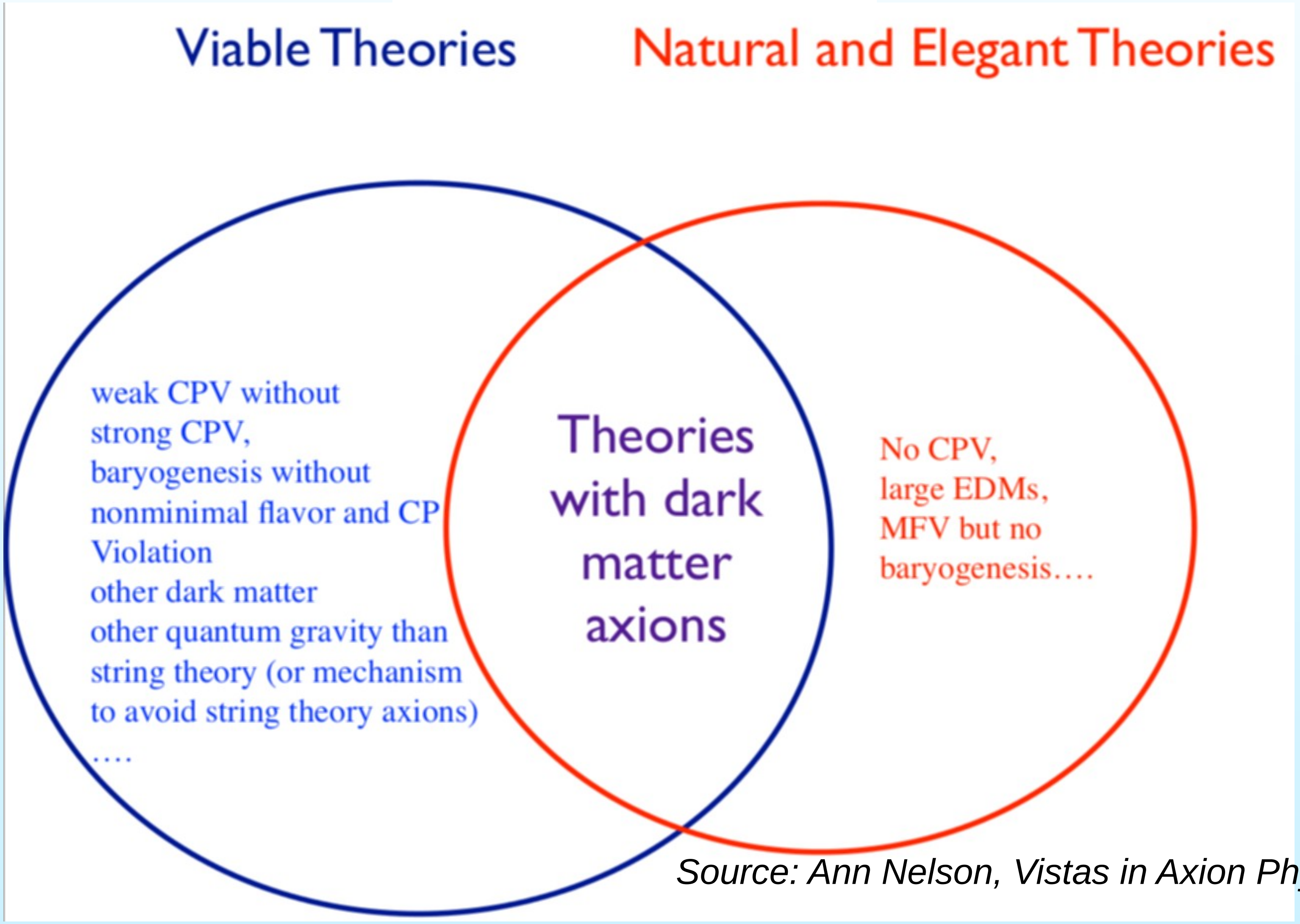




ADMX
and other axion experiments

Gray Rybka
University of Washington
Invisibles Meets Visibles
June, 2015
IFT Madrid

Solves the Strong CP Problem! **Good Dark Matter Candidate!**



Source: Ann Nelson, Vistas in Axion Physics 2012

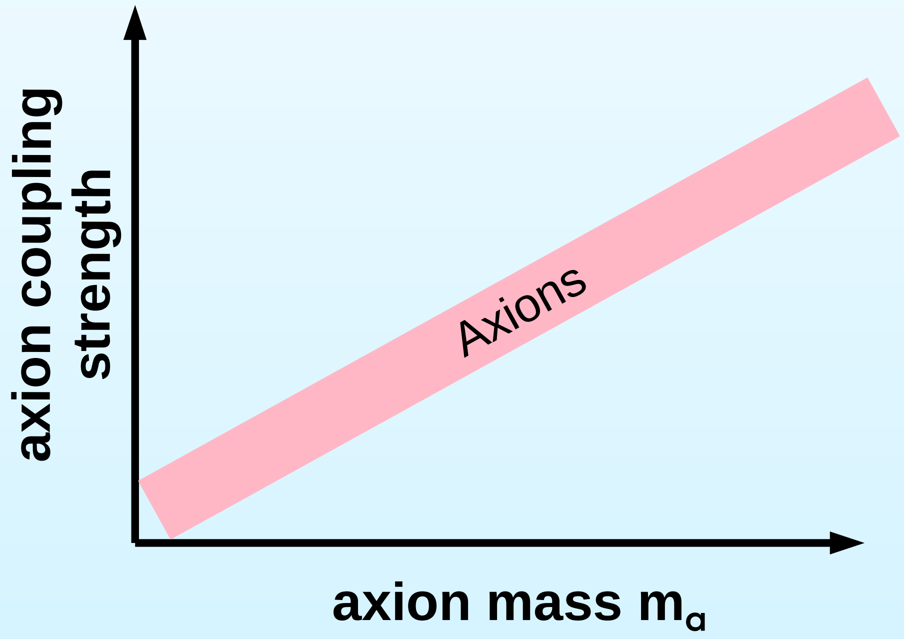
Experimental Axion Couplings

Experimentally, we want to measure a mass and a coupling

- Axion-Nucleon Coupling
- Axion-Electron Coupling
- Axion-Photon Coupling

Coupling and mass are related, but model subtleties make it hard to relate one coupling to another

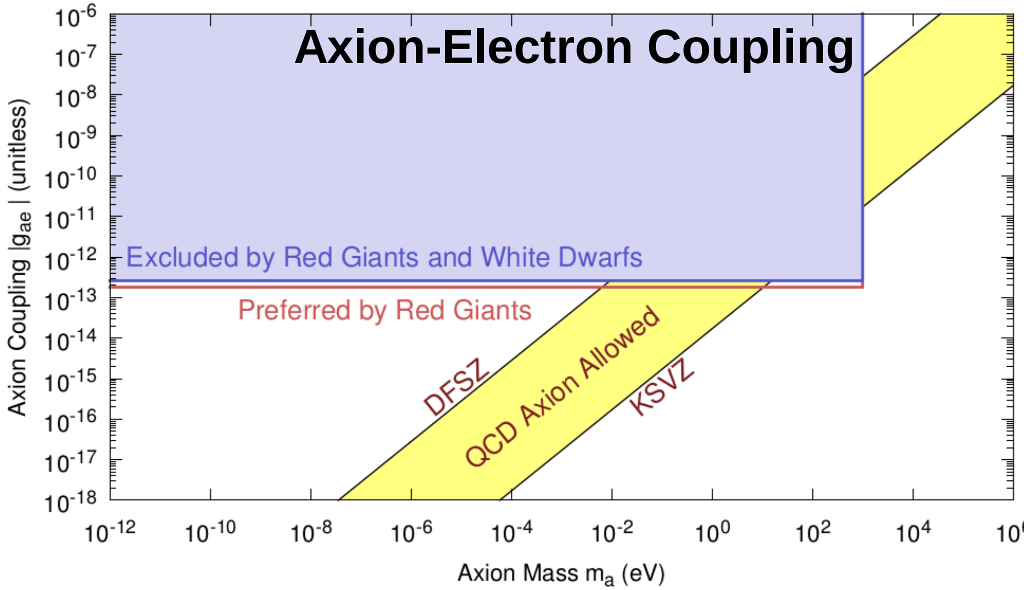
Typical Sensitivity Plot

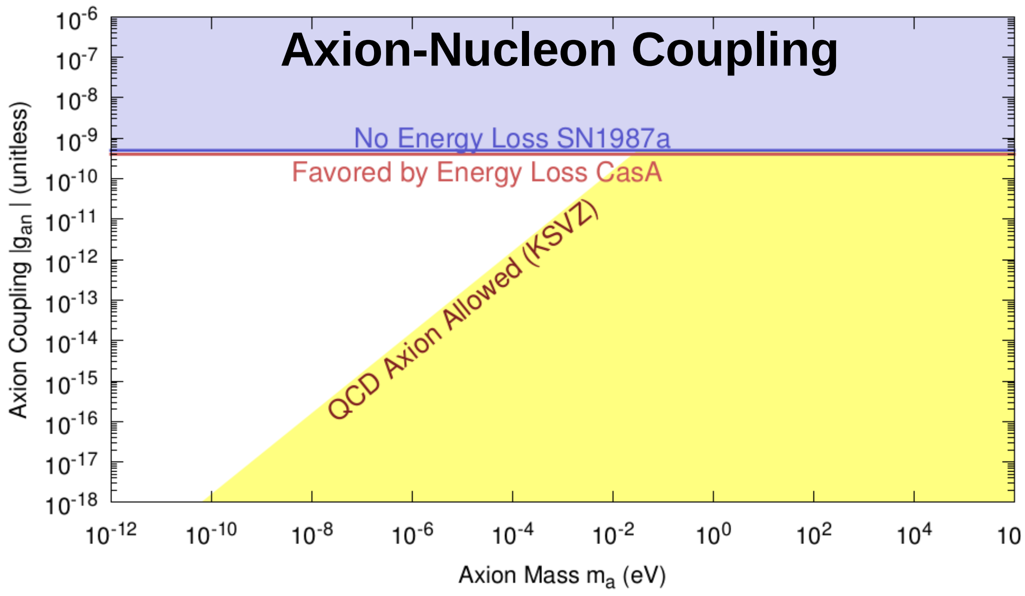


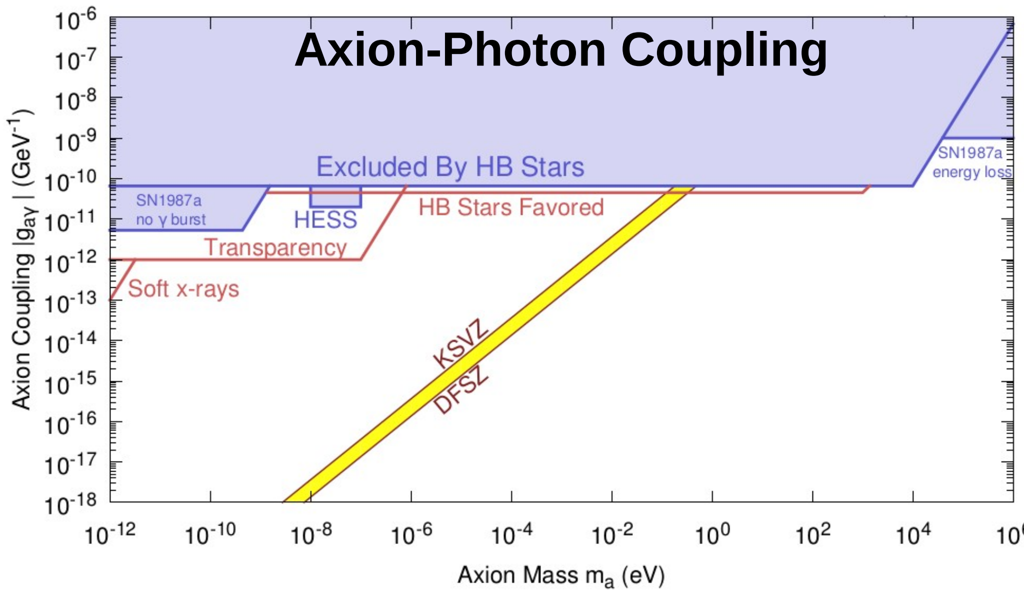
Astrophysical Bounds

Axions

- Are an energy loss mechanism for supernova
- Modify the evolution of red giant stars
- Are a cooling mechanism for white dwarfs
- Modify intergalactic transparency



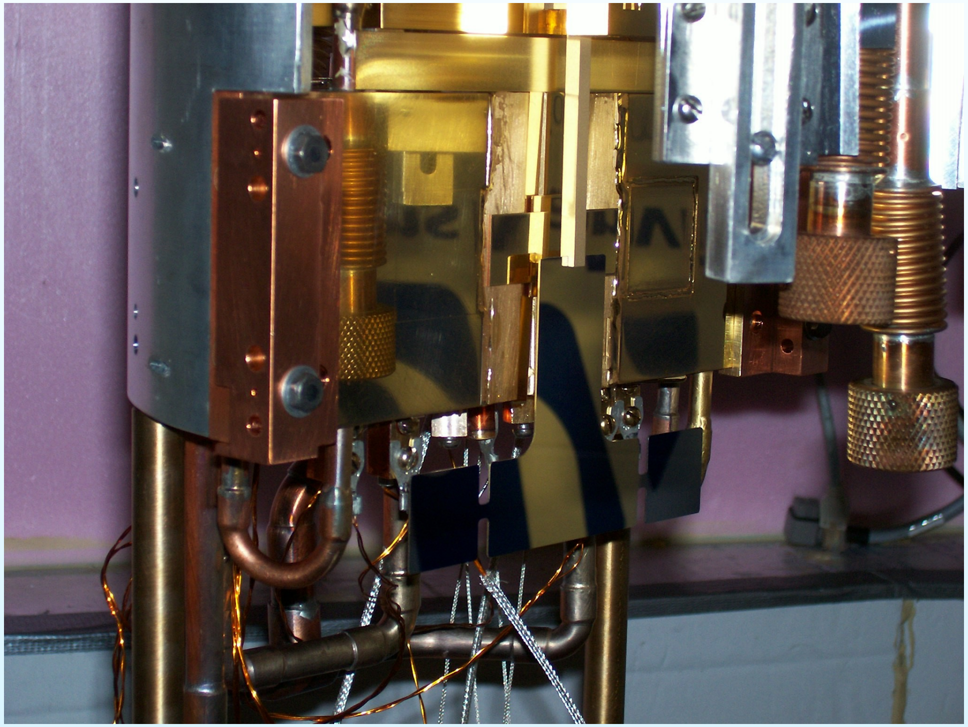




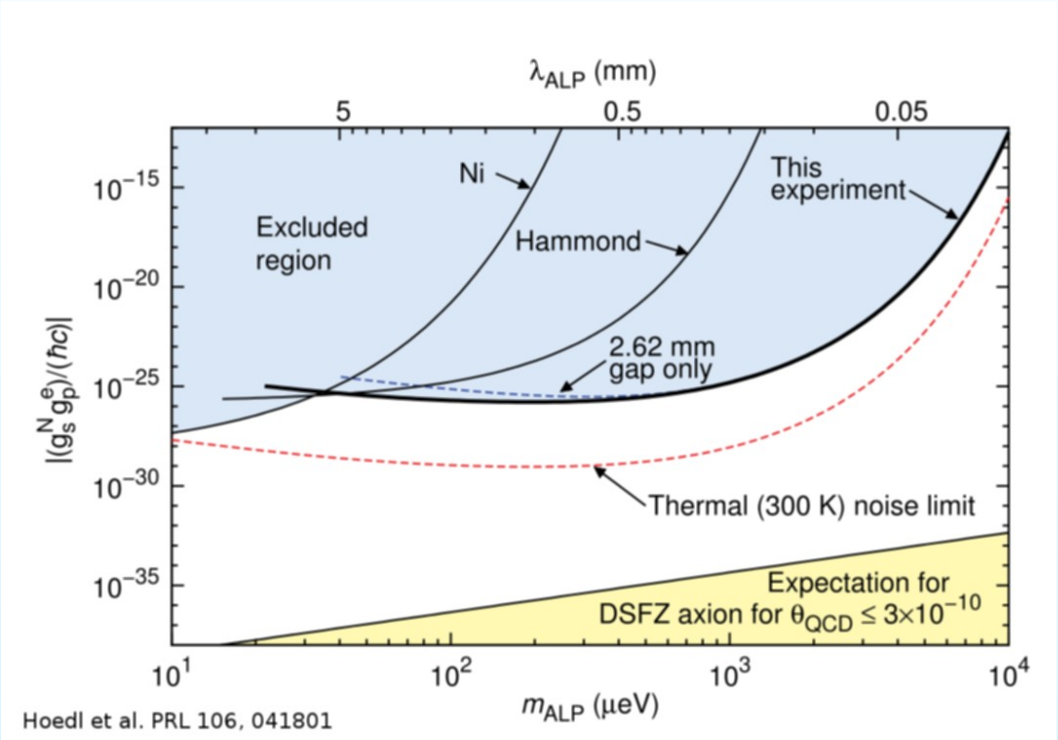
Techniques Discussed

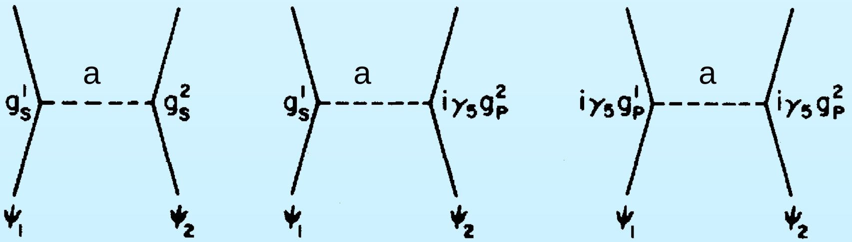
- Short-Range 5th Force Torsion Pendula
- Light Shining Through Walls
- Helioscopes
- Short-Range Force NMR
- Dark Matter NMR
- Axion Dark Matter Cavity Haloscope

Short Range 5th Force Torsion Pendula



Eöt-Wash Group, University of Washington



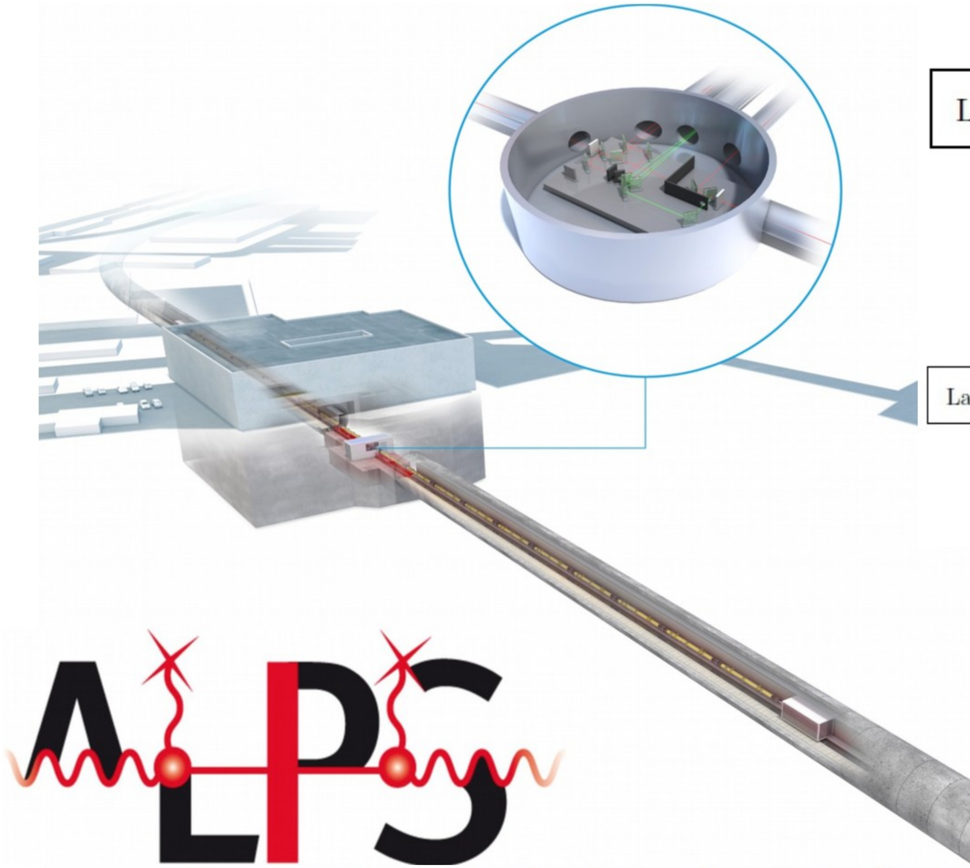


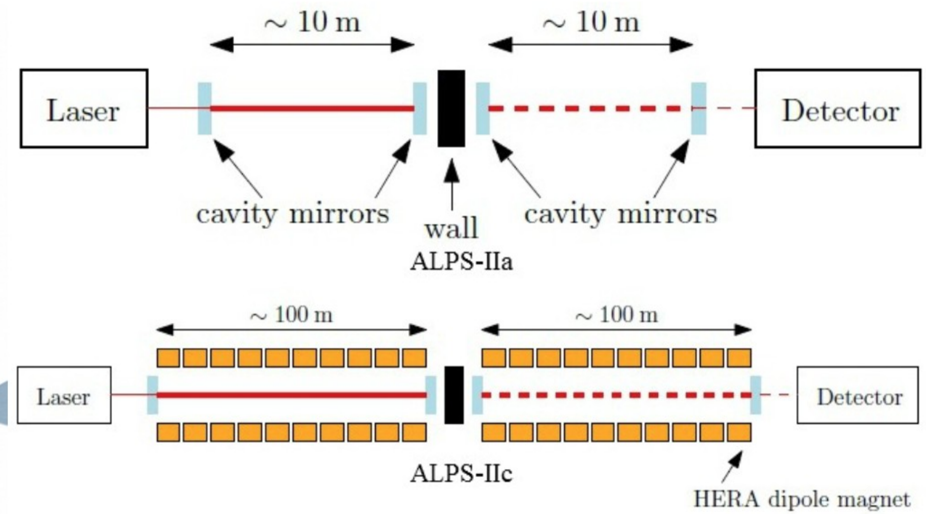
Moody & Wilczek, 1984

Axions behave as force carriers, and could be detected as a short range deviation from gravity

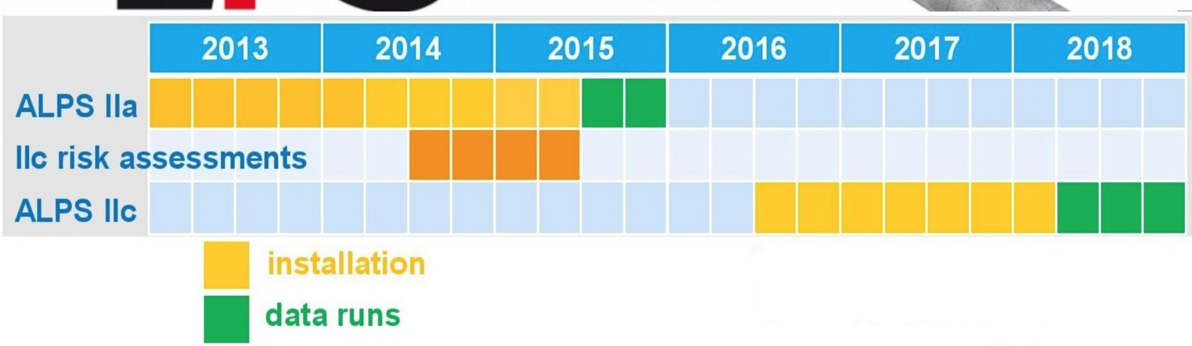
Light-shining-through-a-wall Searches

> ALPS II in prepar. at DESY (in coll. with AEI, U Florida, UHH, U Mainz)





Parameter	Scaling	ALPS I	ALPS IIc	Sens. gain
Effective laser power $P_{\rm laser}$	$g_{a\gamma} \propto P_{\rm laser}^{-1/4}$	1 kW	150 kW	3.5
Rel. photon number flux n_γ	$g_{a\gamma} \propto n_\gamma^{-1/4}$	1 (532 nm)	2 (1064 nm)	1.2
Power built up in RC $P_{\rm RC}$	$g_{a\gamma} \propto P_{reg}^{-1/4}$	1	40,000	14
BL (before& after the wall)	$g_{a\gamma} \propto (BL)^{-1}$	22 Tm	468 Tm	21
Detector efficiency QE	$g_{a\gamma} \propto QE^{-1/4}$	0.9	0.75	0.96
Detector noise DC	$g_{a\gamma} \propto DC^{1/8}$	0.0018 s^{-1}	0.000001 s^{-1}	2.6
Combined improvements				3082

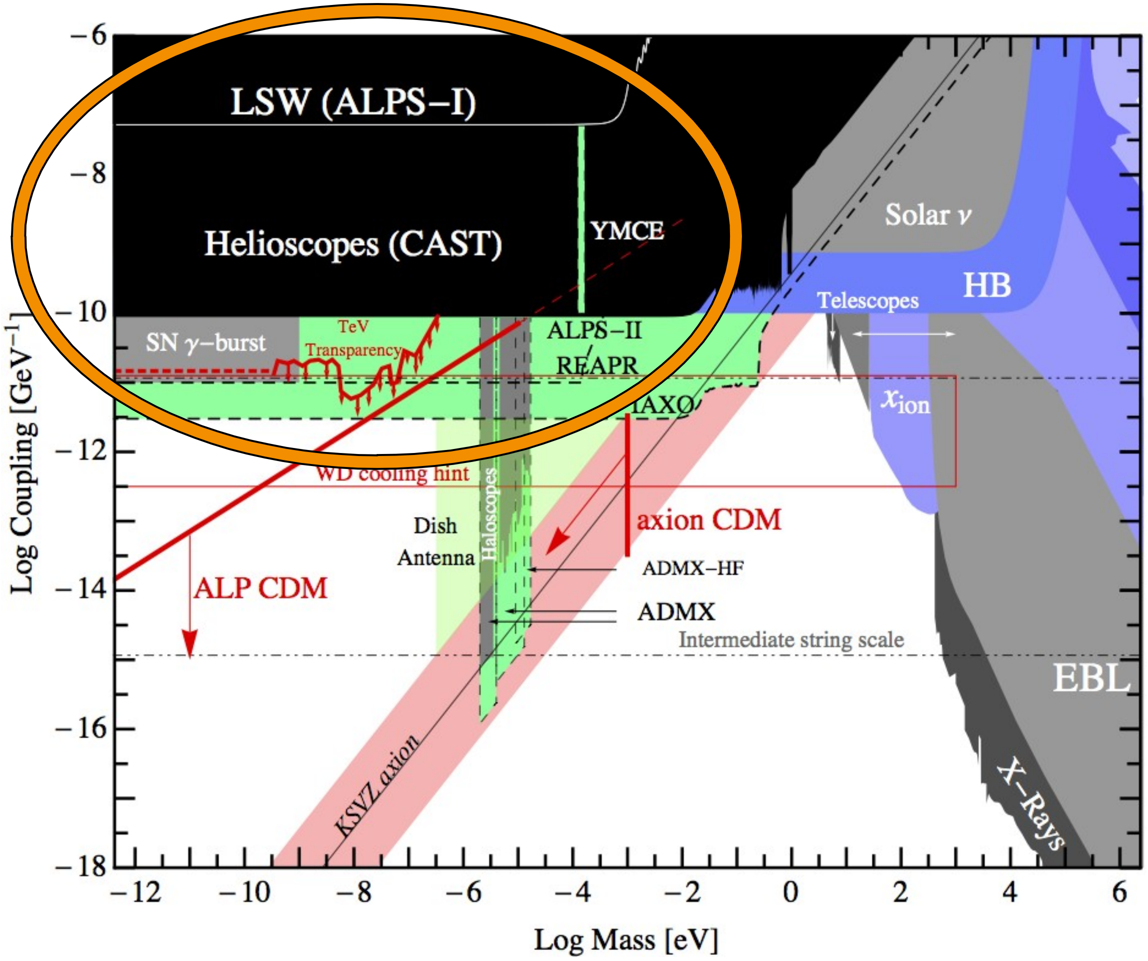


[Bähre et al (ALPS II TDR) 13]

Slide courtesy Andreas Ringwald

Light-shining-through-a-wall Searches

> Crucial test of ALP explanation of excessive HB star energy loss and AGN spectra at VHE



[Essig et al. 1311.0029]

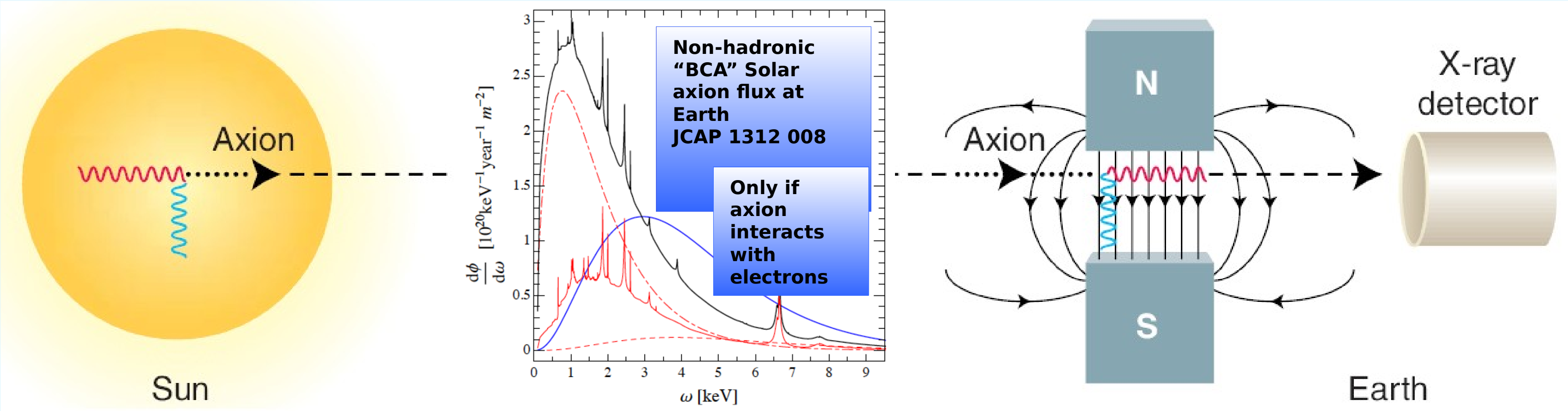
Slide courtesy Andreas Ringwald

Axion Helioscope

- First axion helioscope proposed by P. Sikivie

Sikivie *PRL* 51:1415 (1983)

  - Blackbody photons (keV) in solar core can be converted into axions in the presence of strong electromagentic fields in the plasma
  - Reconversions of axions into x-ray photons possible in strong laboratory magnetic field



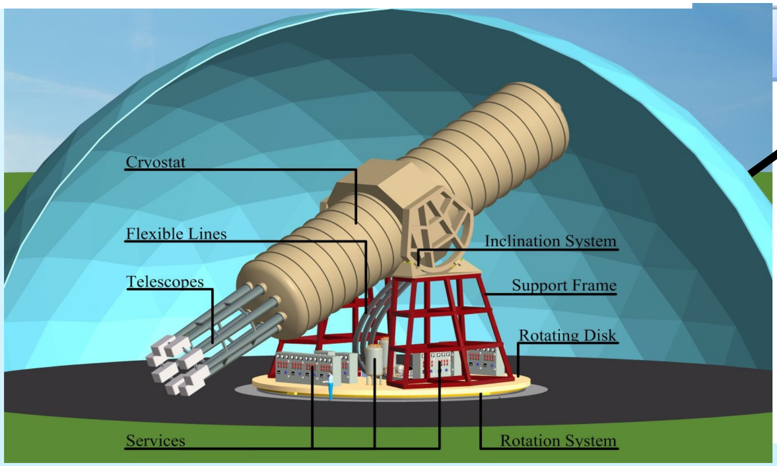
- Idea refined by K. van Bibber by using buffer gas to restore coherence over long magnetic field

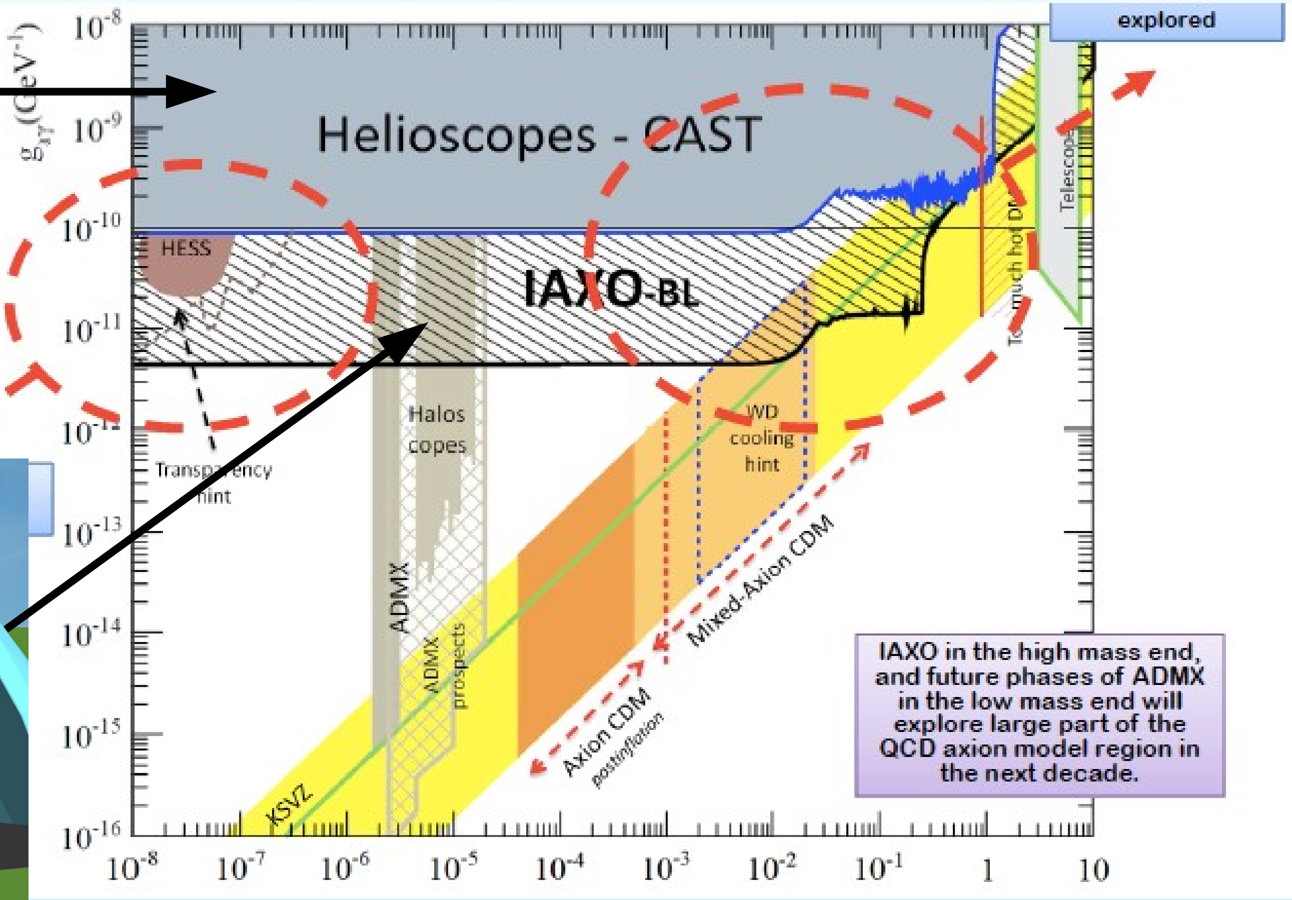
Van Bibber et al. *PhysRevD* 39:2089 (1989)

Helioscope Examples

CAST: LHC dipole magnet pointed at the sun. Has achieved sensitivity to eV-scale QCD axions

IAXO: ambitious proposal to use multiple custom magnets. 4+ years until construction

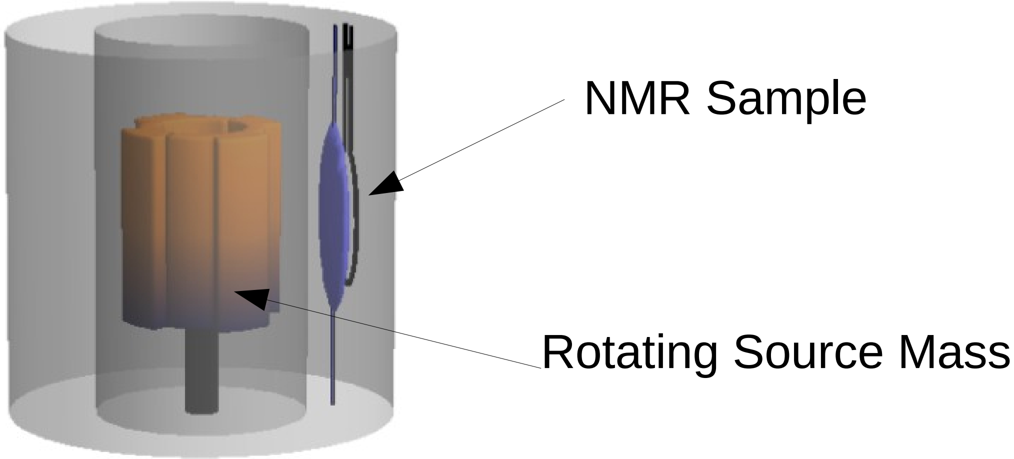




Figures courtesy J. Vogel

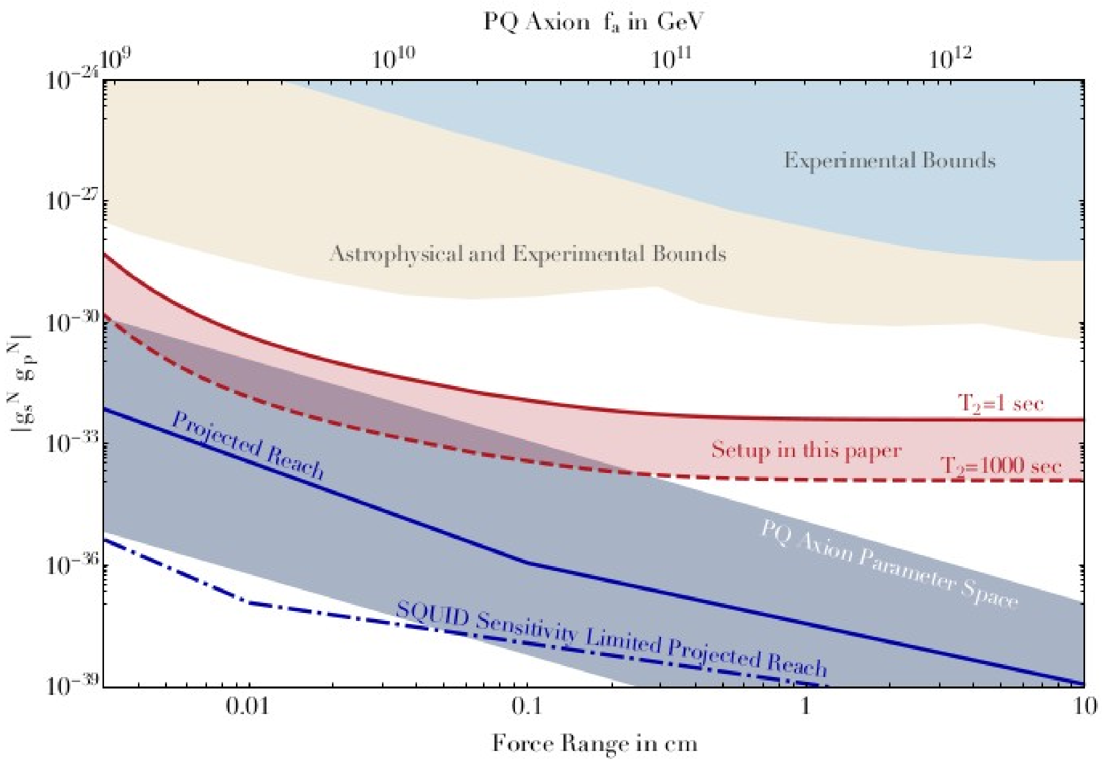
Short Range Force/NMR Application

Combining short range gravity experiments and NMR experiments, a rotating source mass can induce a time varying magnetization in an NMR sample.



Example: ARIADNE experiment

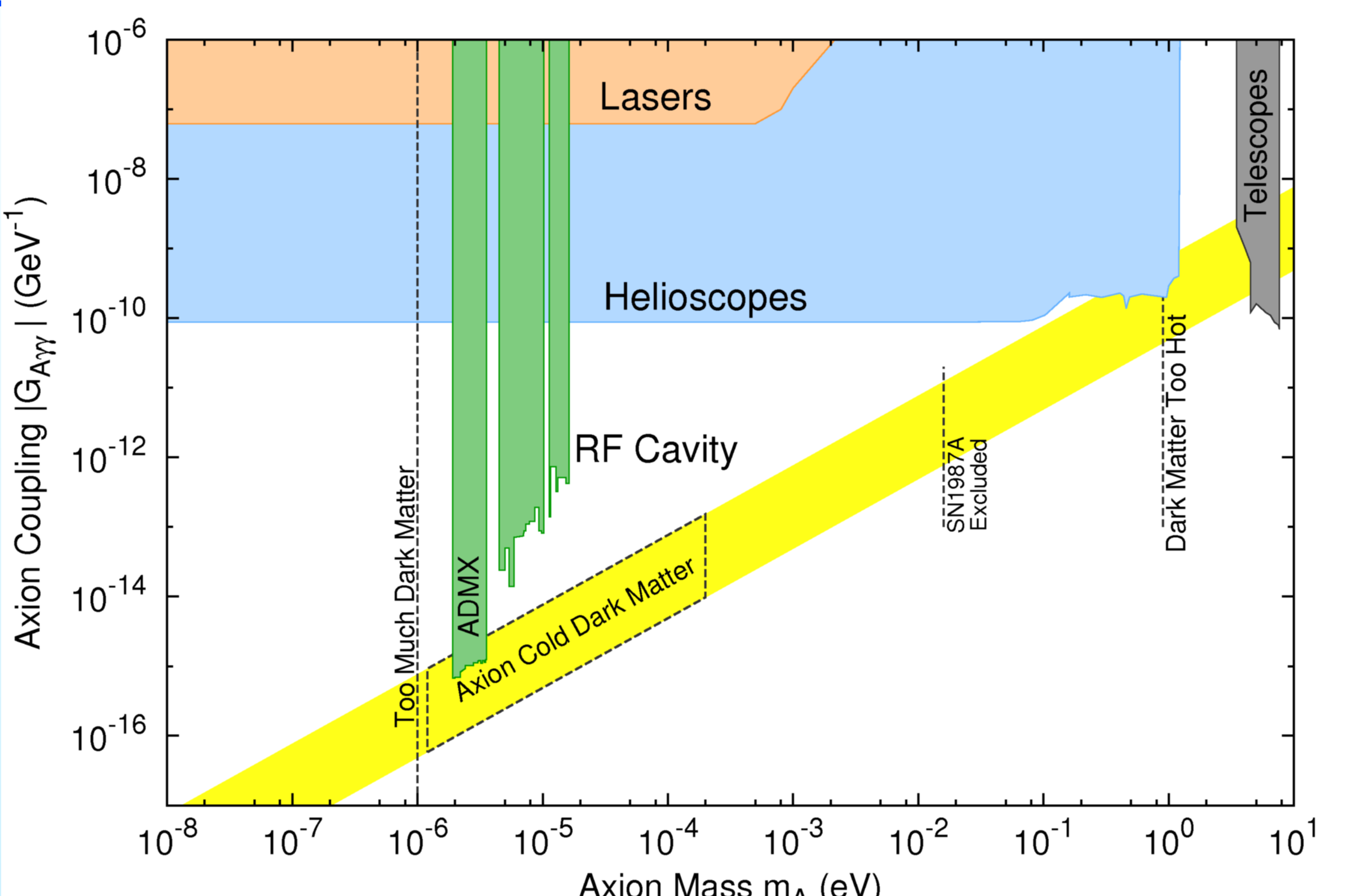
Sensitivity best in meV axion mass range. Future experiments may reach QCD axion coupling sensitivity.



Gray Ryt

Figures from Arvanitaki, & Geraci PRL 113, 161801 (2014)

Axions as Dark Matter

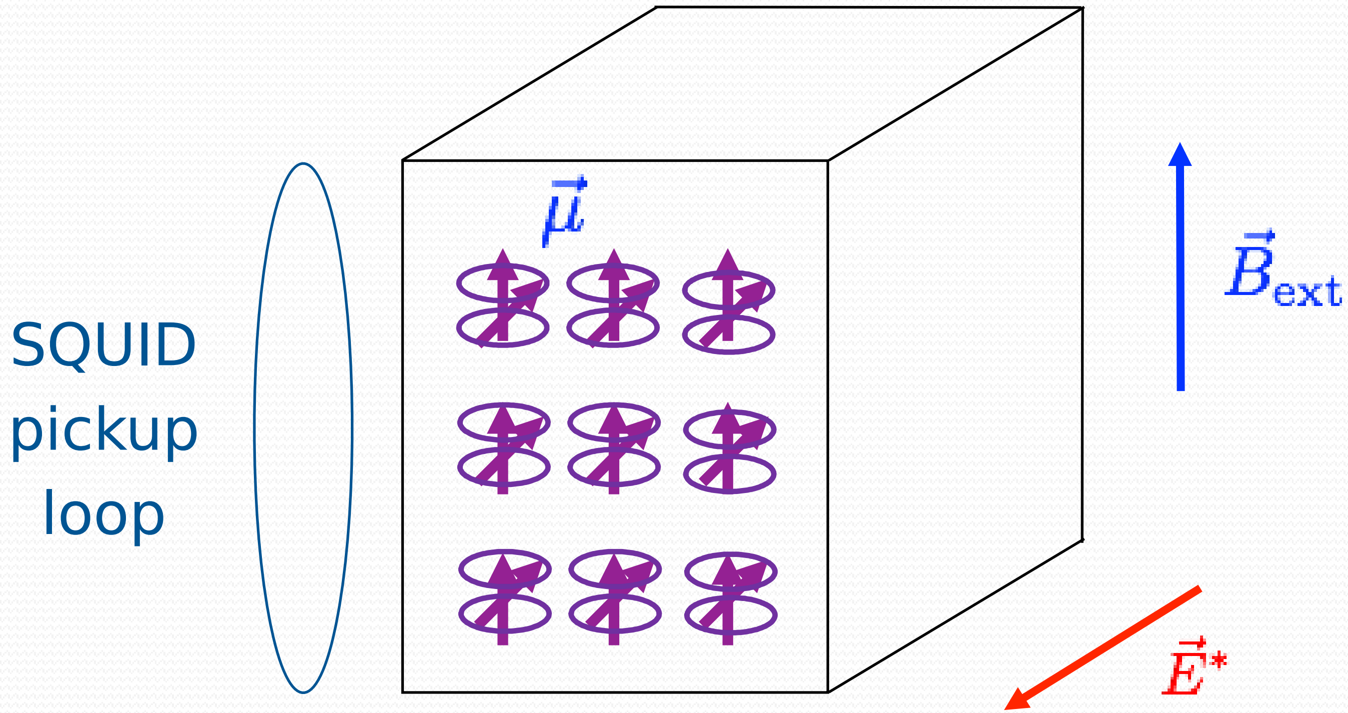


Anthropic Window | **Classical Window** | **Hot DM**

Dark Matter Axions with NMR

Example: CASPER experiment

EDM coupling to axion plays role of oscillating transverse magnetic field

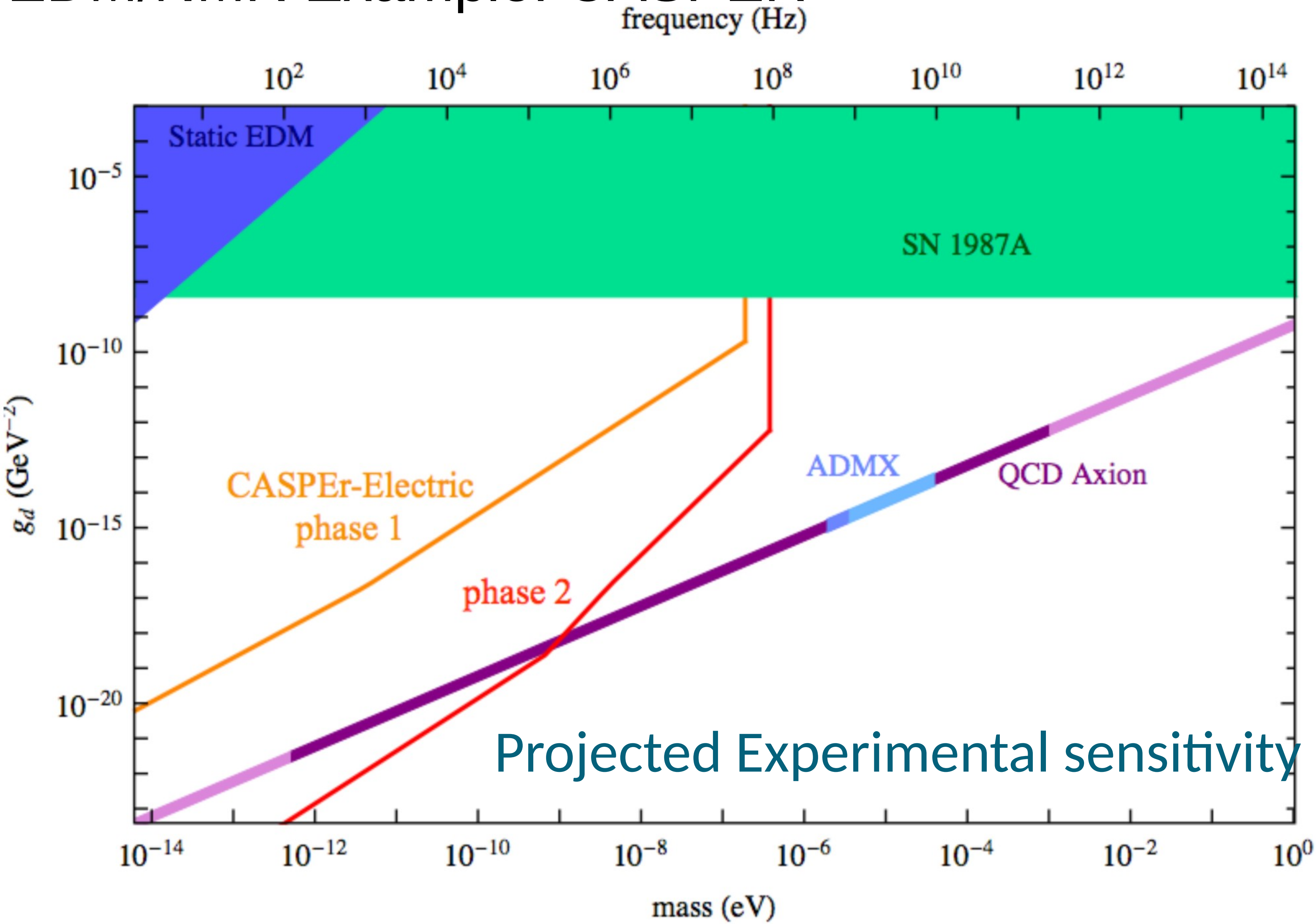


See: Graham & Rajendran PRD 88, 035024 (2013)

Larmor frequency = axion mass ➔ resonant enhancement.

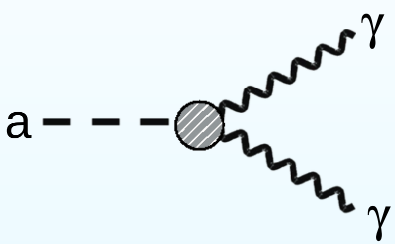
Slide Courtesy Derek Kimball (modified)

EDM/NMR Example: CASPER

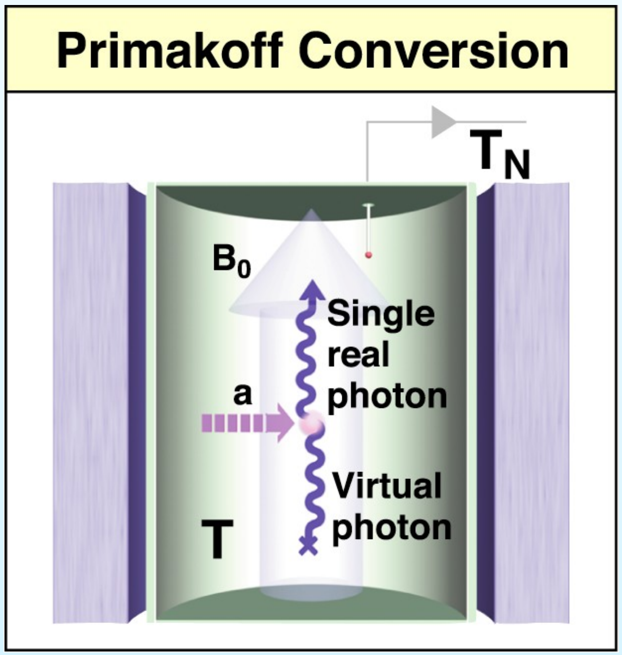


Slide Courtesy Derek Kimball

Axion Haloscope



$$\frac{\partial\left(\mathbf{E}^2/2\right)}{\partial t} - \mathbf{E}\cdot\left(\nabla\times\mathbf{B}\right) = g_{a\gamma}\dot{a}\left(\mathbf{E}\cdot\mathbf{B}\right)$$



Dark Matter Axions will convert to photons in a magnetic field.

The measurement is enhanced if the photon's frequency corresponds to the cavity's resonant frequency.

See: Sikivie, Phys. Rev. Lett. 1983

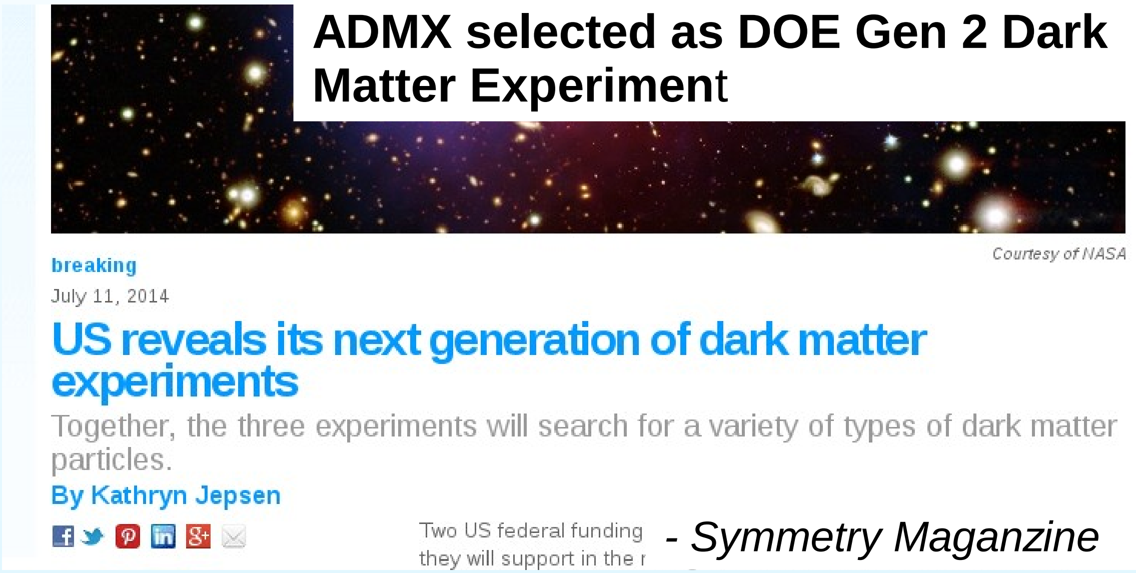
You Want:
-Large Cavity Volume
-High Magnetic Field
-High Cavity Q

You Don't Want:
-High Thermal Noise
-High Amplifier Noise

ADMX: Axion Dark Matter eXperiment

Science, Nov. 2013, 552 - 555

ADMX selected as DOE Gen 2 Dark Matter Experiment


Courtesy of NASA

breaking

July 11, 2014

US reveals its next generation of dark matter experiments

Together, the three experiments will search for a variety of types of dark matter particles.

By Kathryn Jepsen

Two US federal funding
they will support in the r

- Symmetry Maganzine

Collaboration:

- *University of Washington*
- *LLNL*
- *University of Florida*
- *Yale*
- *UC Berkeley*
- *NRAO*
- *FNAL*
- *..and growing*

ADMX Design

Field Cancellation Coil

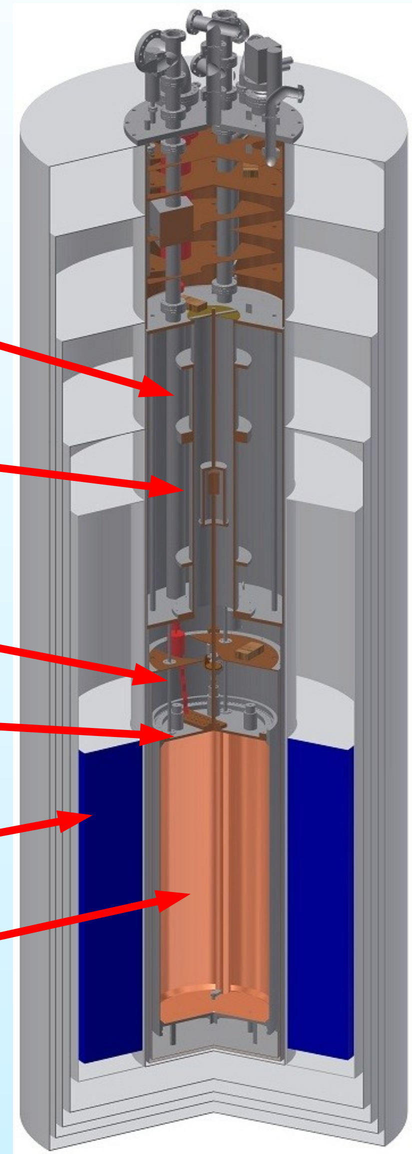
SQUID Amplifier package

Refrigeration

Antennas

8 Tesla Magnet

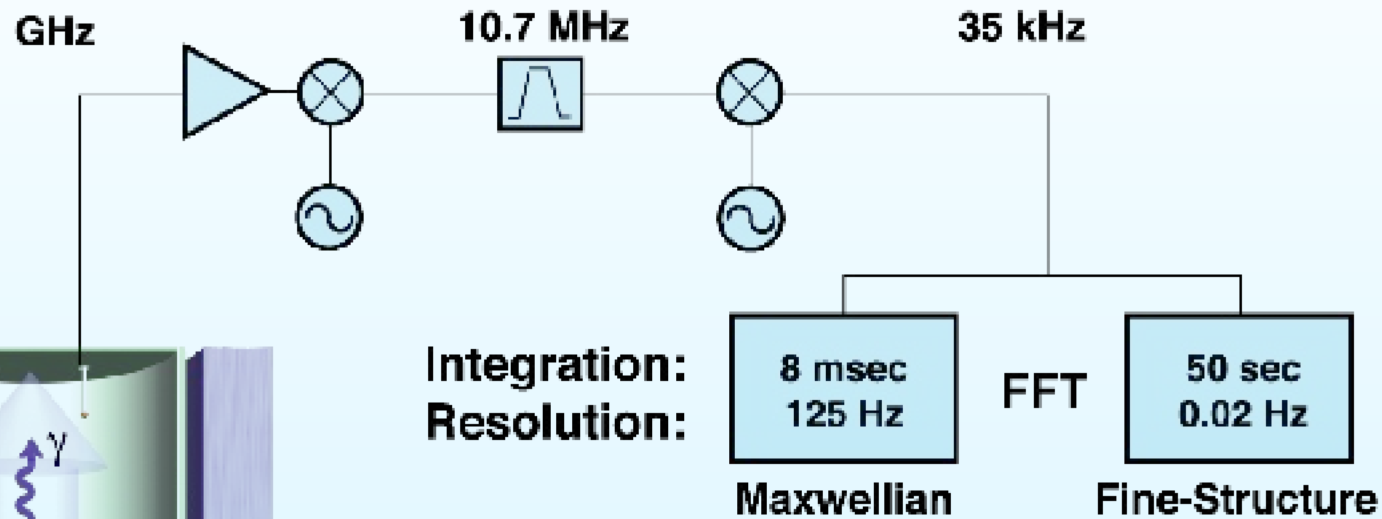
Microwave cavity

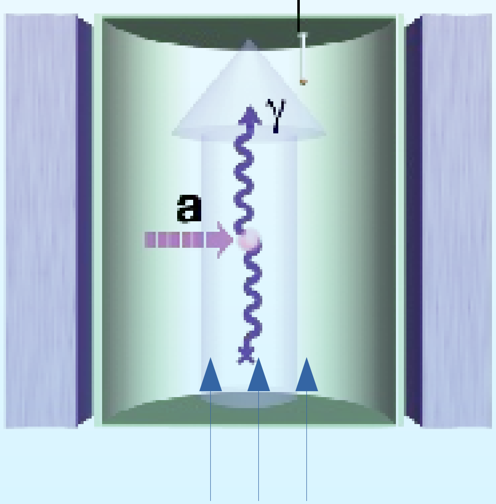


Insert + Magnet Schematic

Insert extraction from magnet

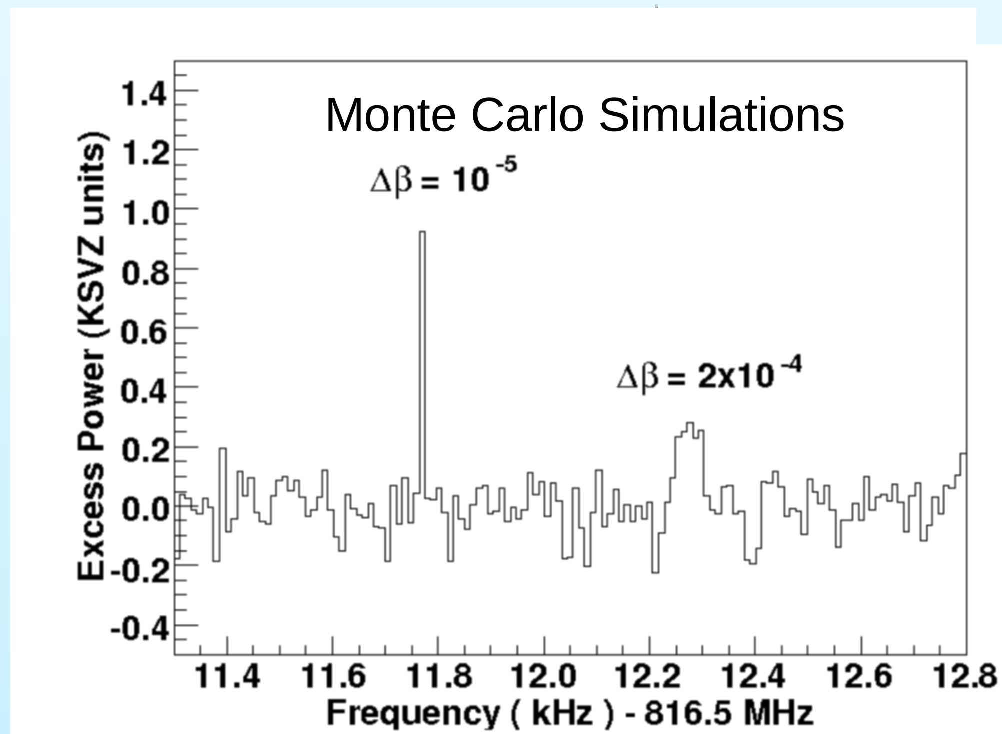
ADMX Receiver



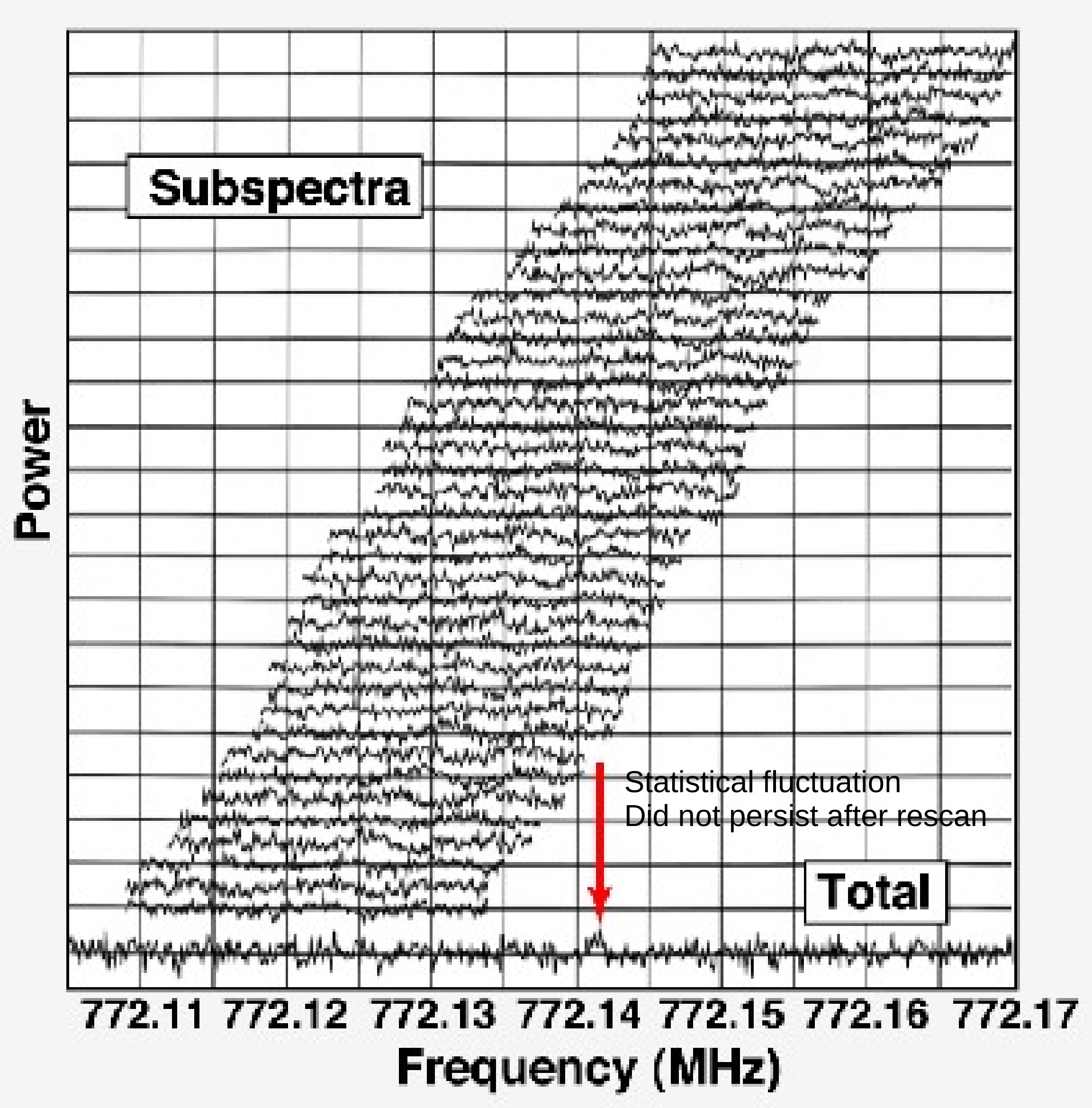


B=8 Tesla

Axions, stimulated by a magnetic field, decay into microwave photons which resonate in the cooled cavity and are amplified and read out



Axion Search Cadence



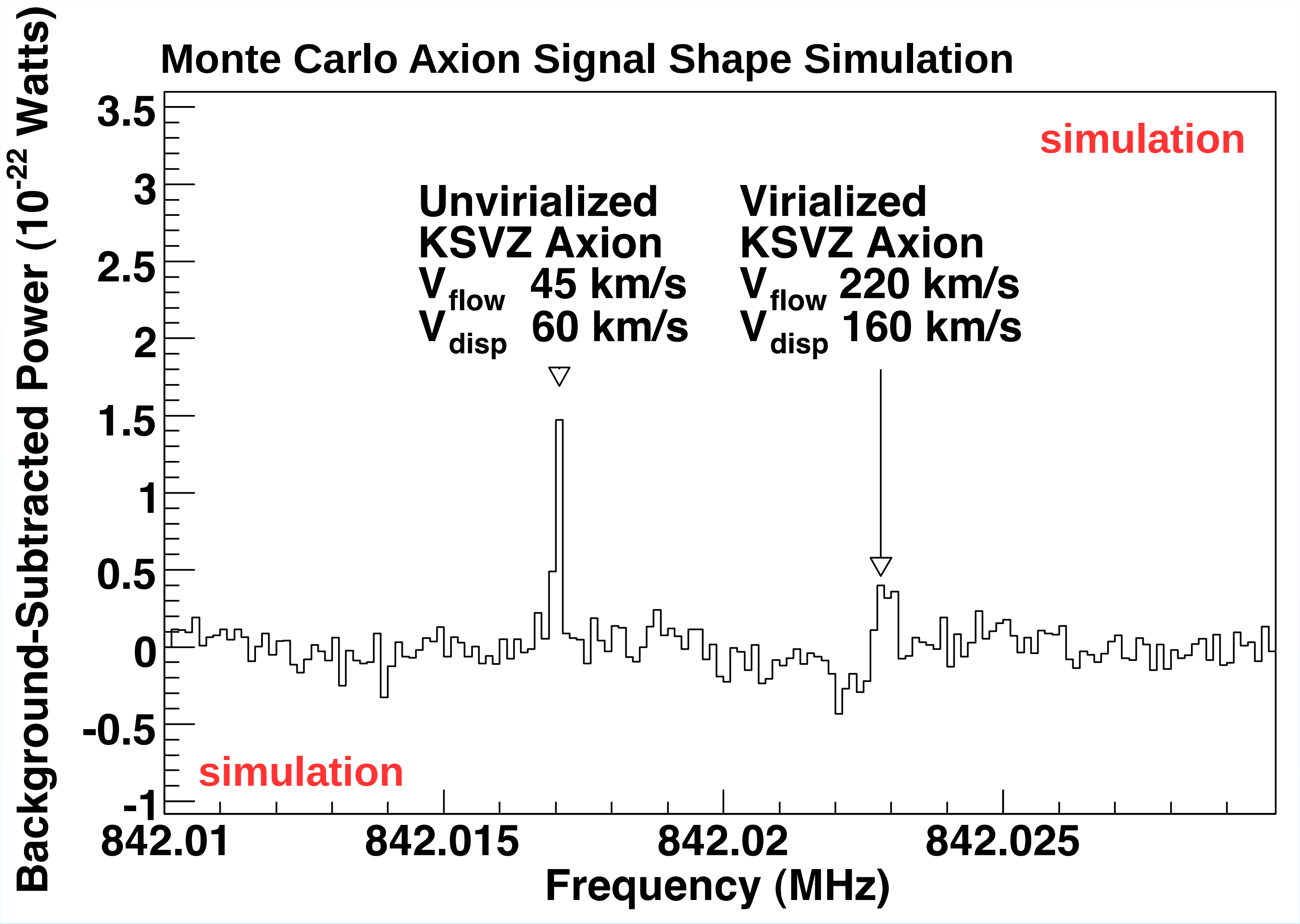
Cavity resonant frequency is tuned by two movable rods

Power spectra are measured at each rod position

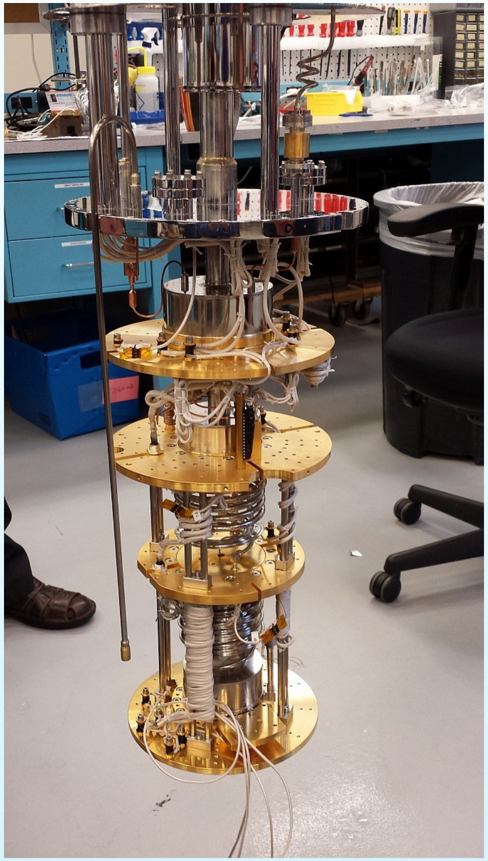
Axion signal would appear as a constant power excess

Most backgrounds do not persist

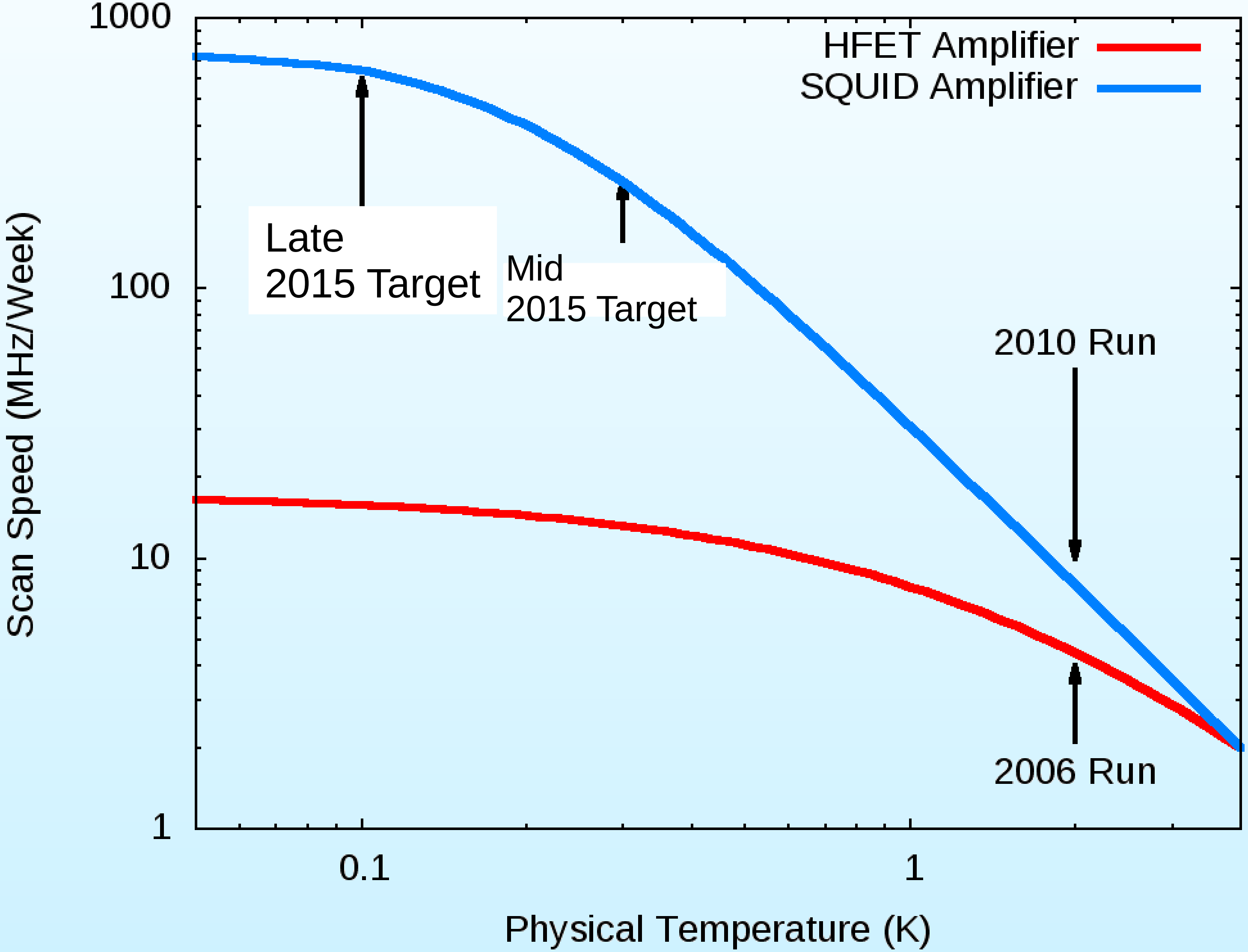
ADMX Expected Signal



ADMX Gen 2 Key technologies improve scan speed immensely



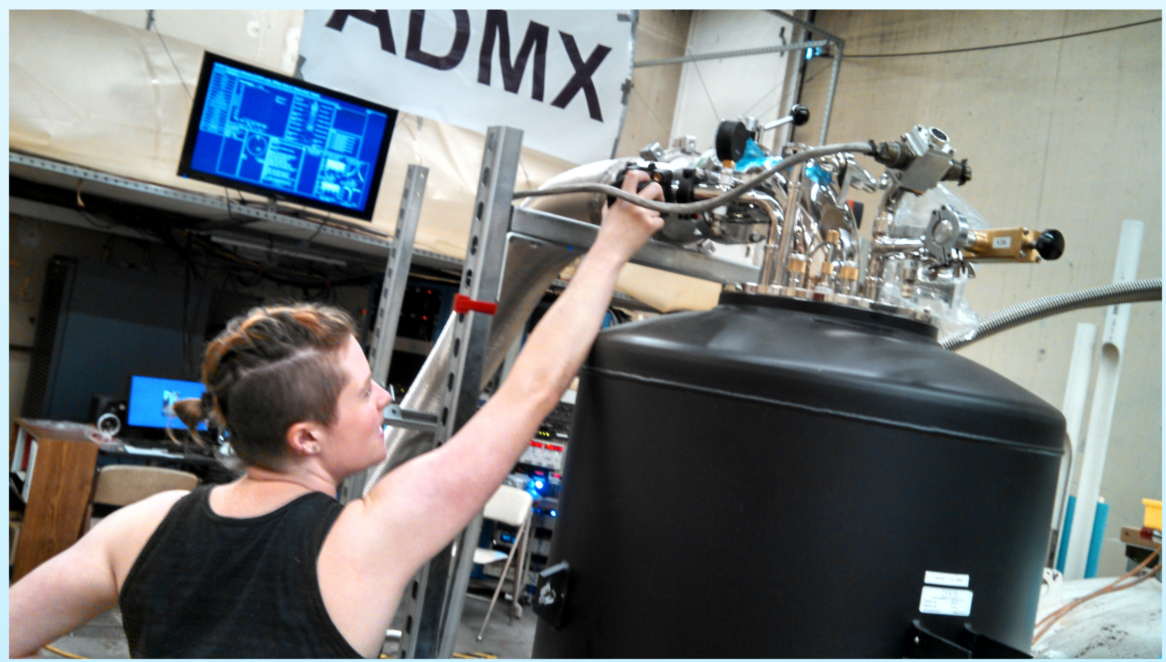
Dilution refrigerator under test. Currently being packed for shipment to to UW.



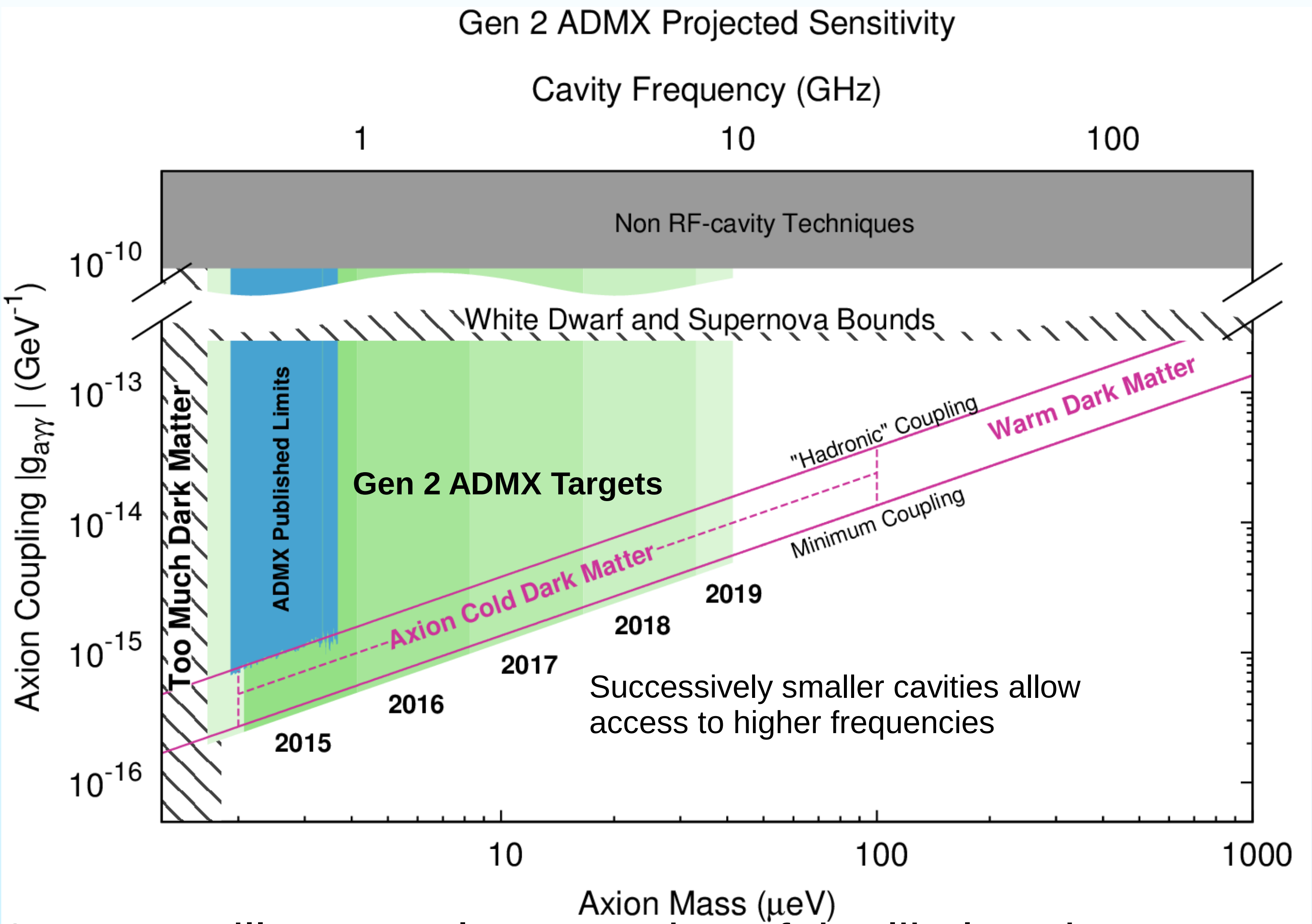
ADMX Gen 2 Status

Dilution Refrigerator Commissioning in progress at the University of Washington

All other subsystems are ready to go.



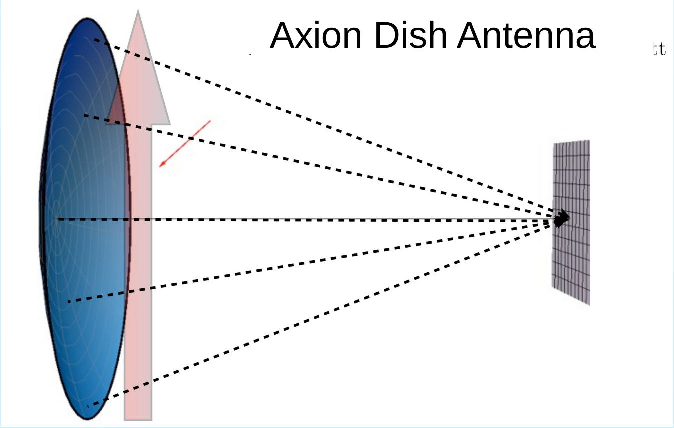
Gen 2 ADMX Program

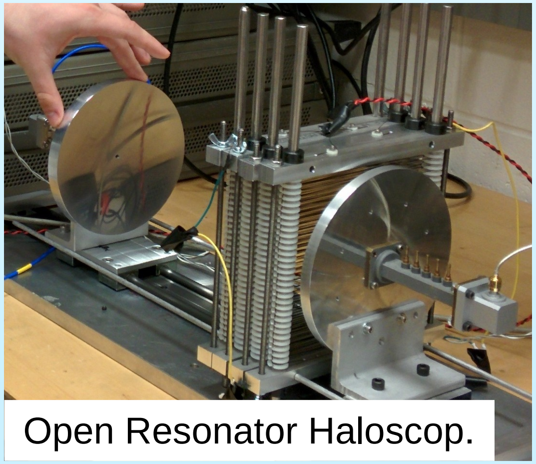


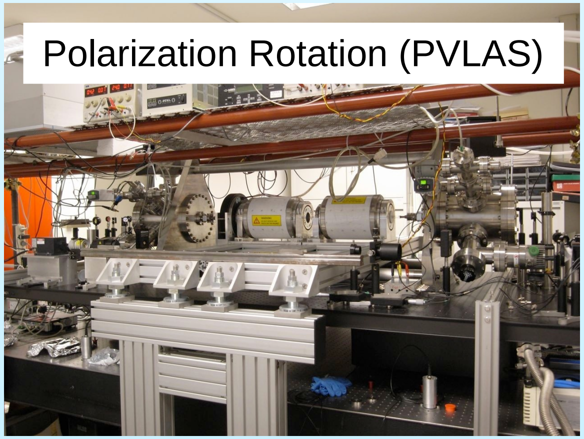
Gen 2 ADMX will cover a large portion of the likely axion mass range at minimal couplings. We have a good chance at finding the axion.

Ideas Not Covered

- Accelerator Beam Dumps
- Photon polarization rotation
- Open Resonator Haloscopes
- Dish Antennae
- Rydberg Atoms
- Matched Astrophysical/Ground Searches
- LHC Searches
- Germanium/Xenon Searches


Axion Dish Antenna


Open Resonator Haloscop.


Polarization Rotation (PVLAS)

Conclusions

The Axion is compelling: it represents an elegant explanation to the unsolved problems of the strong CP problem and the nature of dark matter.

The Axion is exciting: new ideas about how to look for axions are arising and established ideas have been implemented

The Axion is within our grasp: experiments in the new future (such as ADMX) will be exploring a large portion of plausible axion parameters.