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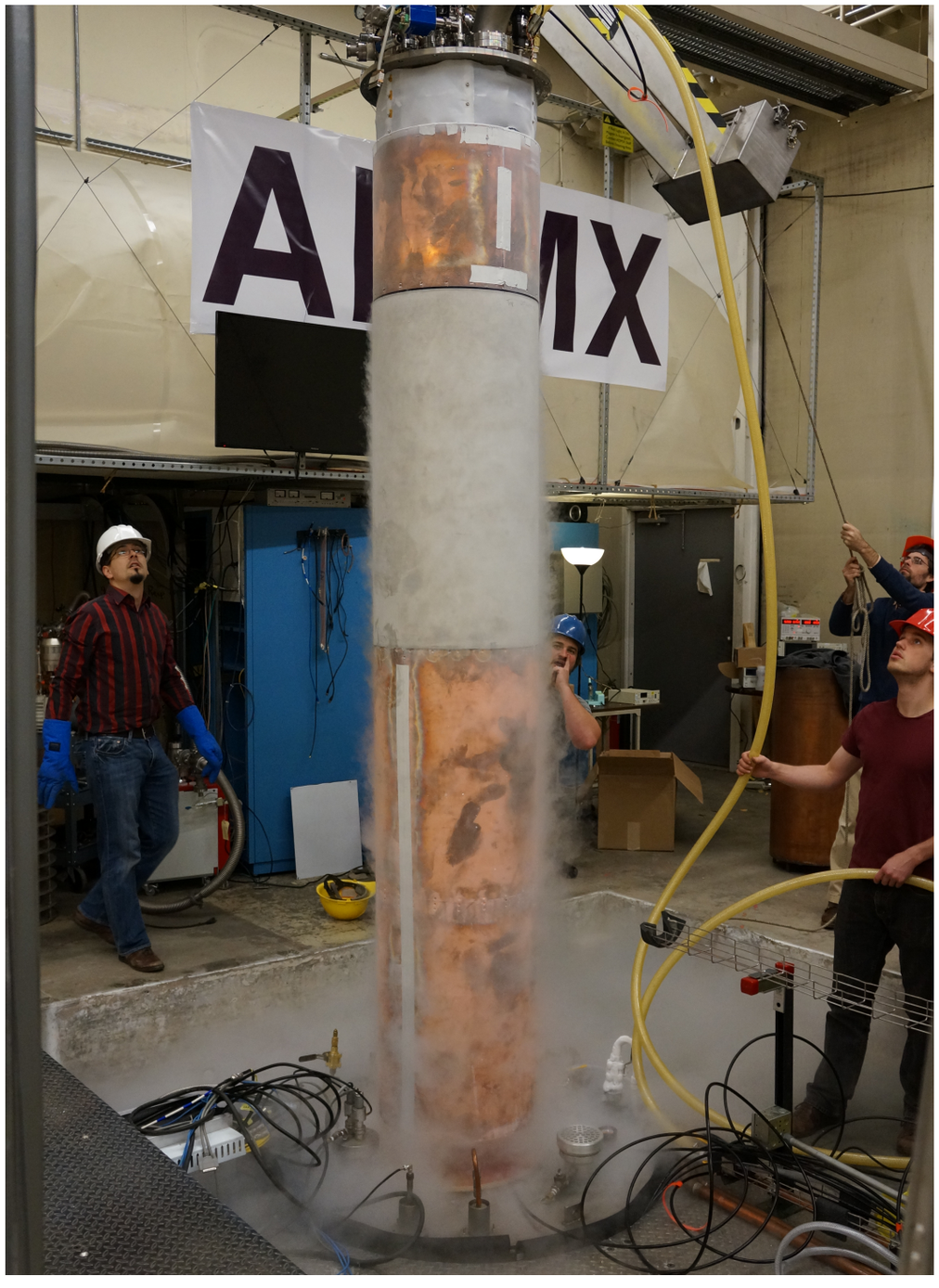
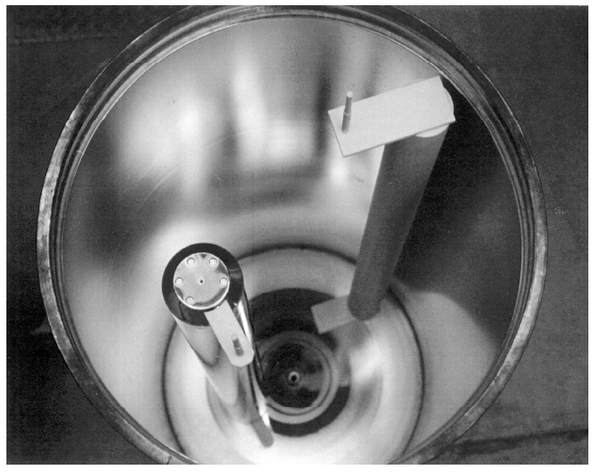
ADMX Axion Search

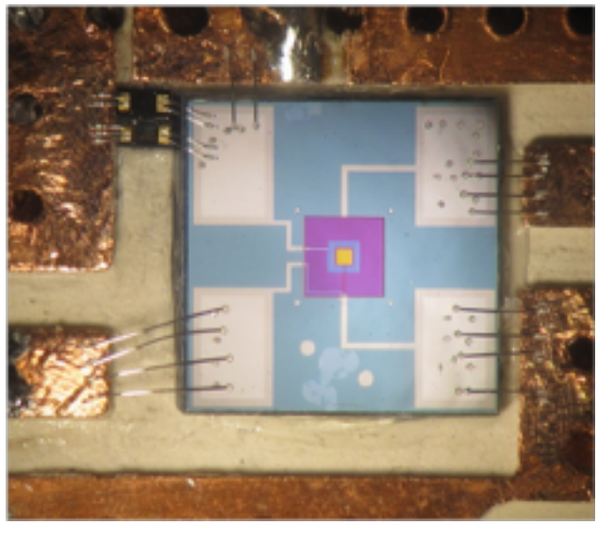


Ed Daw

SUSY 2014

[for the ADMX collaboration]





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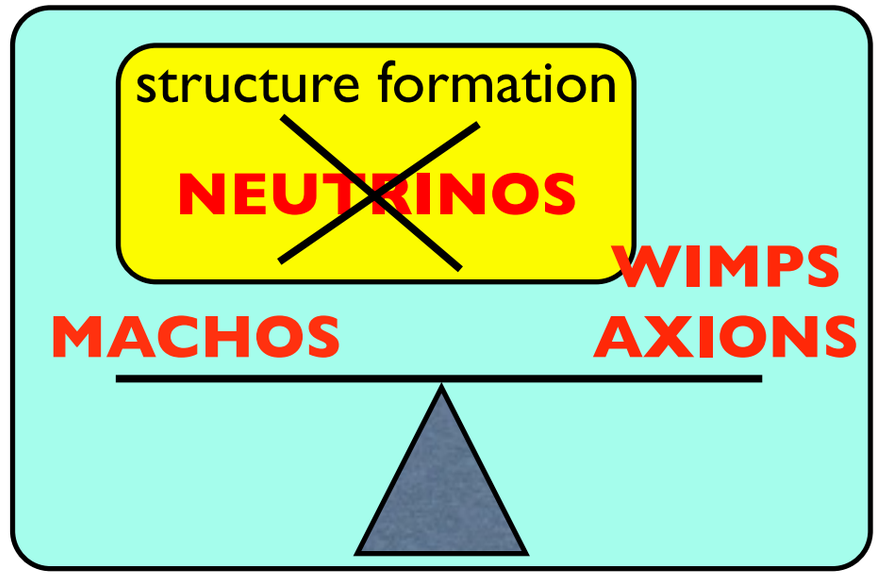
Dark Matter Problem: Historical Perspective

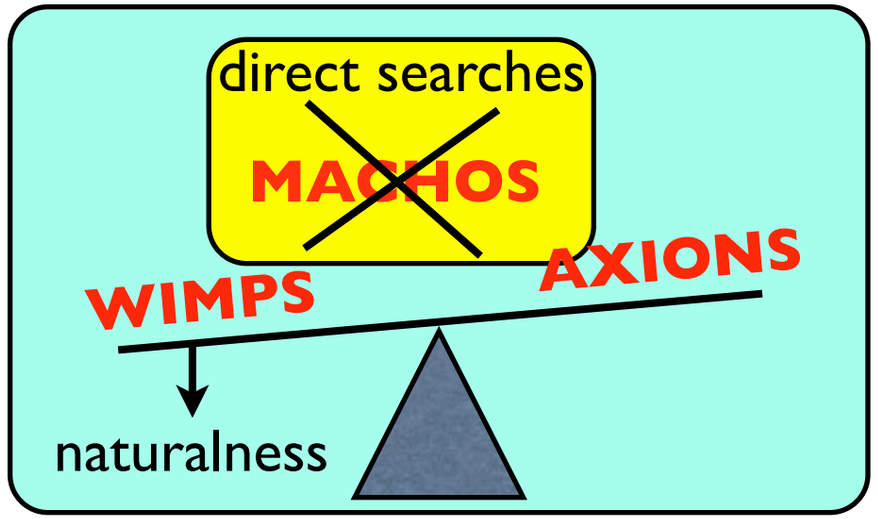
1990s:

IMPRECISE COSMOLOGY
INCOMPLETE ELECTROWEAK PHYSICS
DARK ENERGY NOT GENERALLY BELIEVED
ROTATION CURVES IMPLY DARK MATTER
COLD FOR STRUCTURE FORMATION,
BUT MANY STILL BELIEVE IN BARYONIC DM.



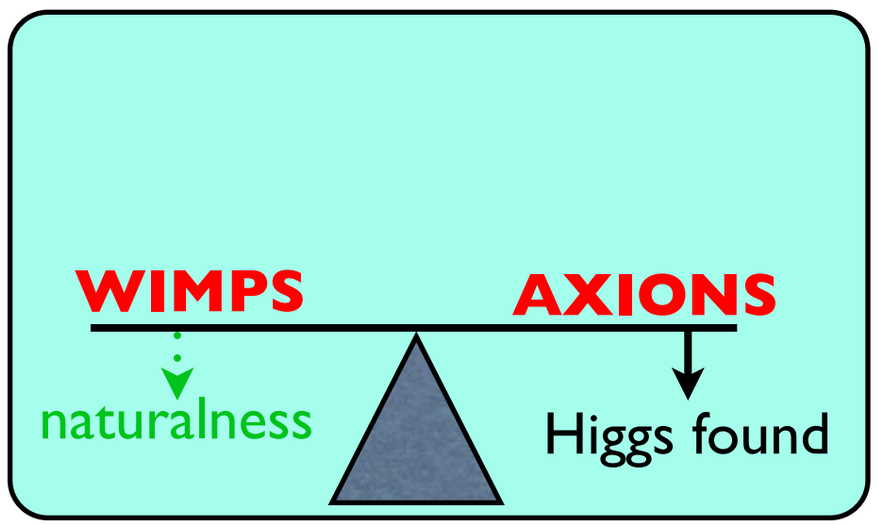
2000s:

PRECISION COSMOLOGY
INCOMPLETE ELECTROWEAK PHYSICS
EVIDENCE FOR DARK ENERGY
EVIDENCE FOR COLD DARK MATTER
BARYONS CAN'T BE A LARGE COMPONENT



2010s:

HIGHER PRECISION COSMOLOGY
MORE COMPLETE ELECTROWEAK PHYSICS
DARK ENERGY PROBES RAMPING UP
STRONG EVIDENCE FOR COLD, NON BARYONIC DARK MATTER.
PARAMETER SPACE FOR NEW ELECTROWEAK PHYSICS SHRINKING, ERODING NATURALNESS ARGUMENT.



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What are Axions ?

QCD VACUUM — QUARK MASSES

$$\mathcal{L}_{\mathrm{CPV}} = \frac{(\Theta + \arg\det M)}{32\pi^2}\vec{E}_{\mathrm{QCD}} \cdot \vec{B}_{\mathrm{QCD}}$$

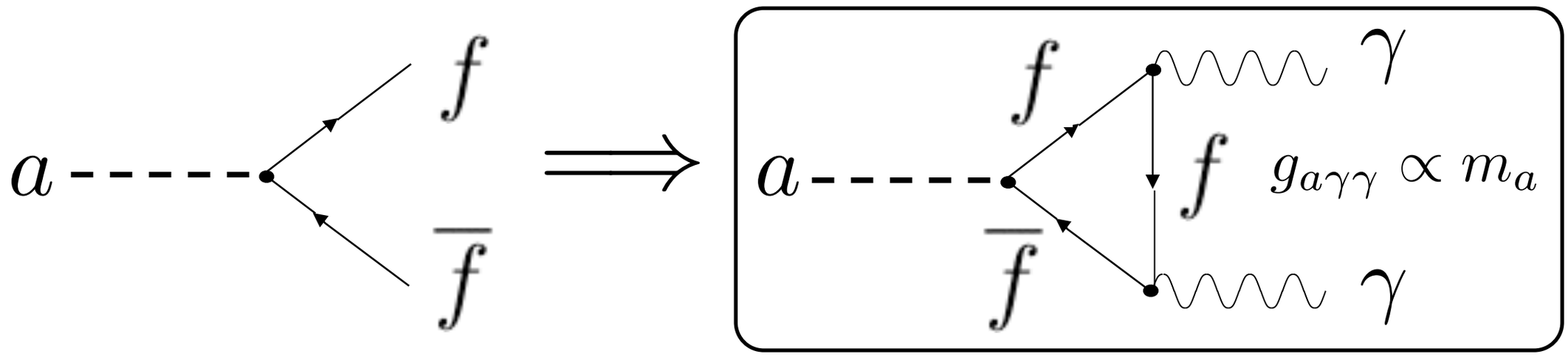
BUT searches for strong CP violation (like cryoEDM) so far tell us that

$$\Theta + \arg\det\ M < 10^{-9}$$

Either both of these terms are zero (unlikely) or they add to zero (new physics)

'New' Physics - the Peccei Quinn mechanism: $a = \Theta + \arg\det\ M$

A new U(1) symmetry is spontaneously broken at energy scale f_{PQ} and this forces $a \to 0$ .The axion is the Goldstone Boson for the SSB.



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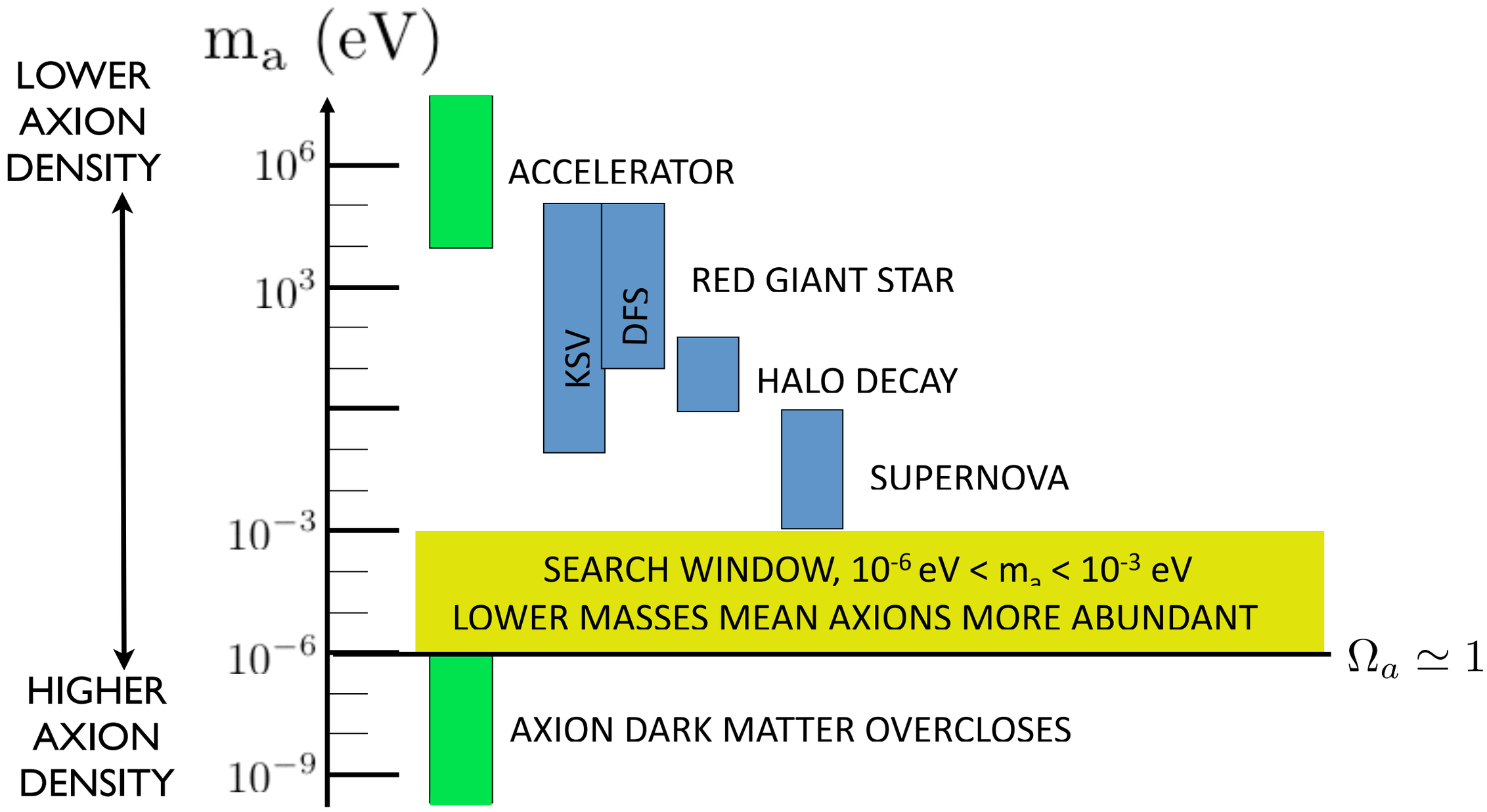
Axions as Dark Matter

Misalignment production produces axions in early Universe at energy scale $f_{\rm PQ}$. Abundance related to mass by $\Omega_a \propto 1/m_a^{7/6}$. Astrophysics further constrains dark matter axion mass.



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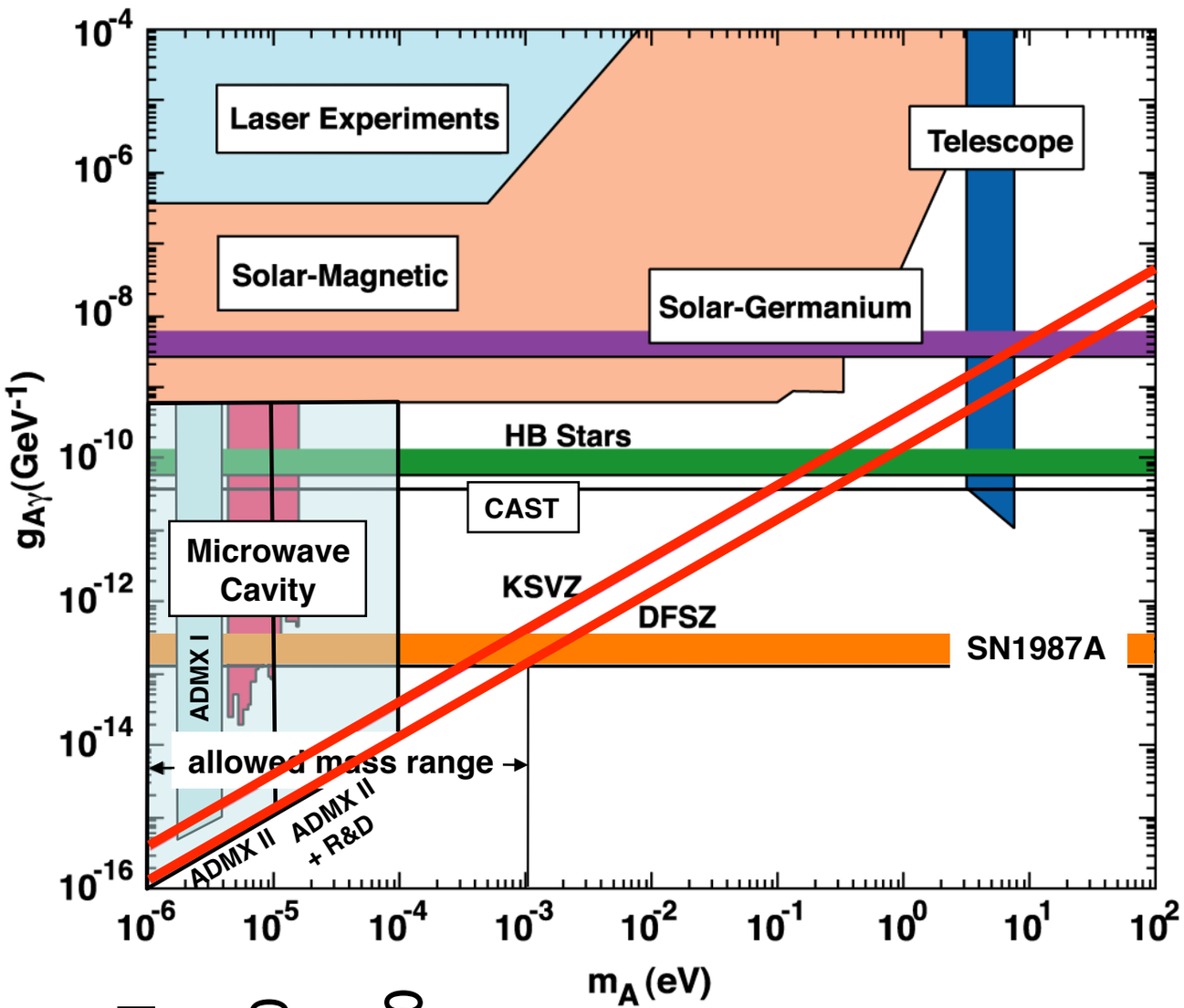
Other limits and searches for axions



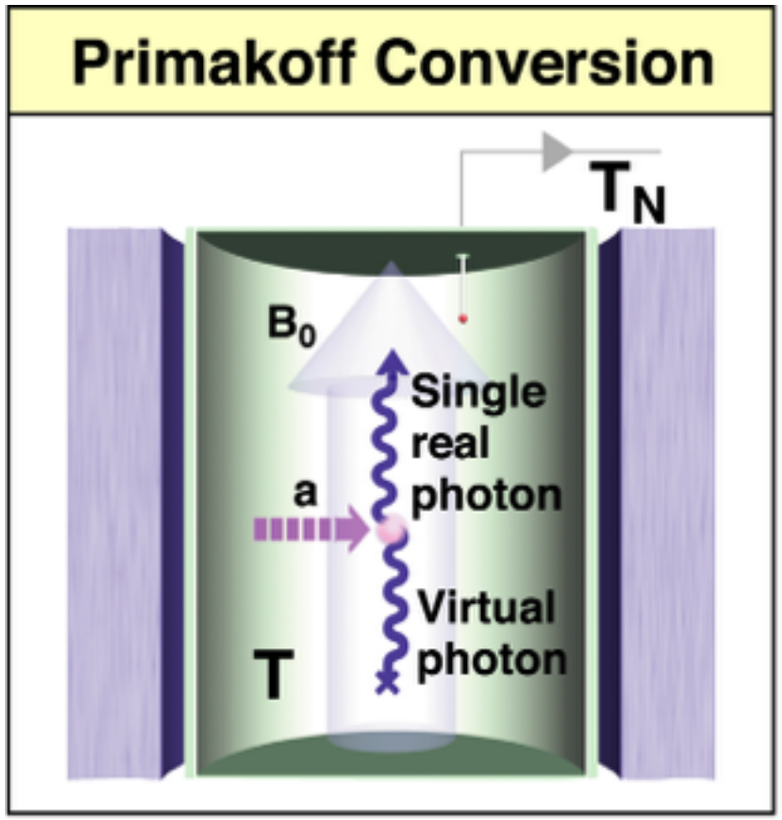
1

0.08

0.0046

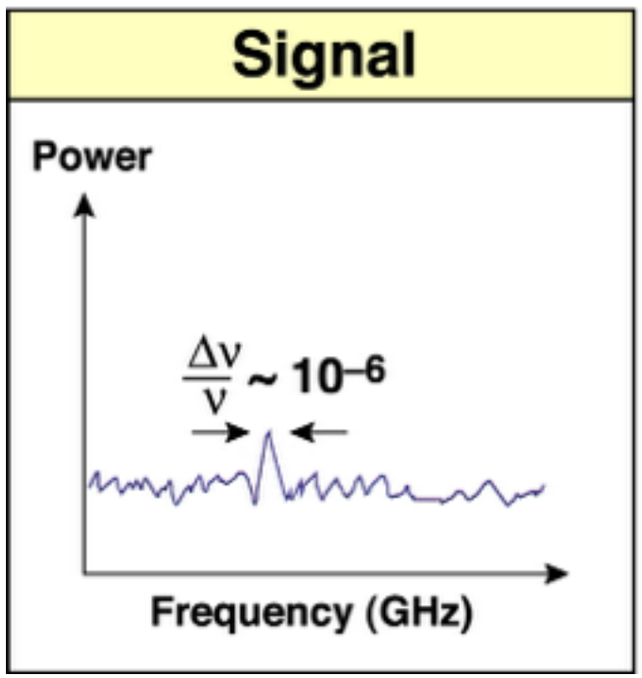
Ω_a

Some experimental details of the RF-cavity technique



- The conversion is resonant, i.e. the frequency must equal the mass + K. E.
- The total system noise temperature $T_S = T + T_N$ is the critical factor

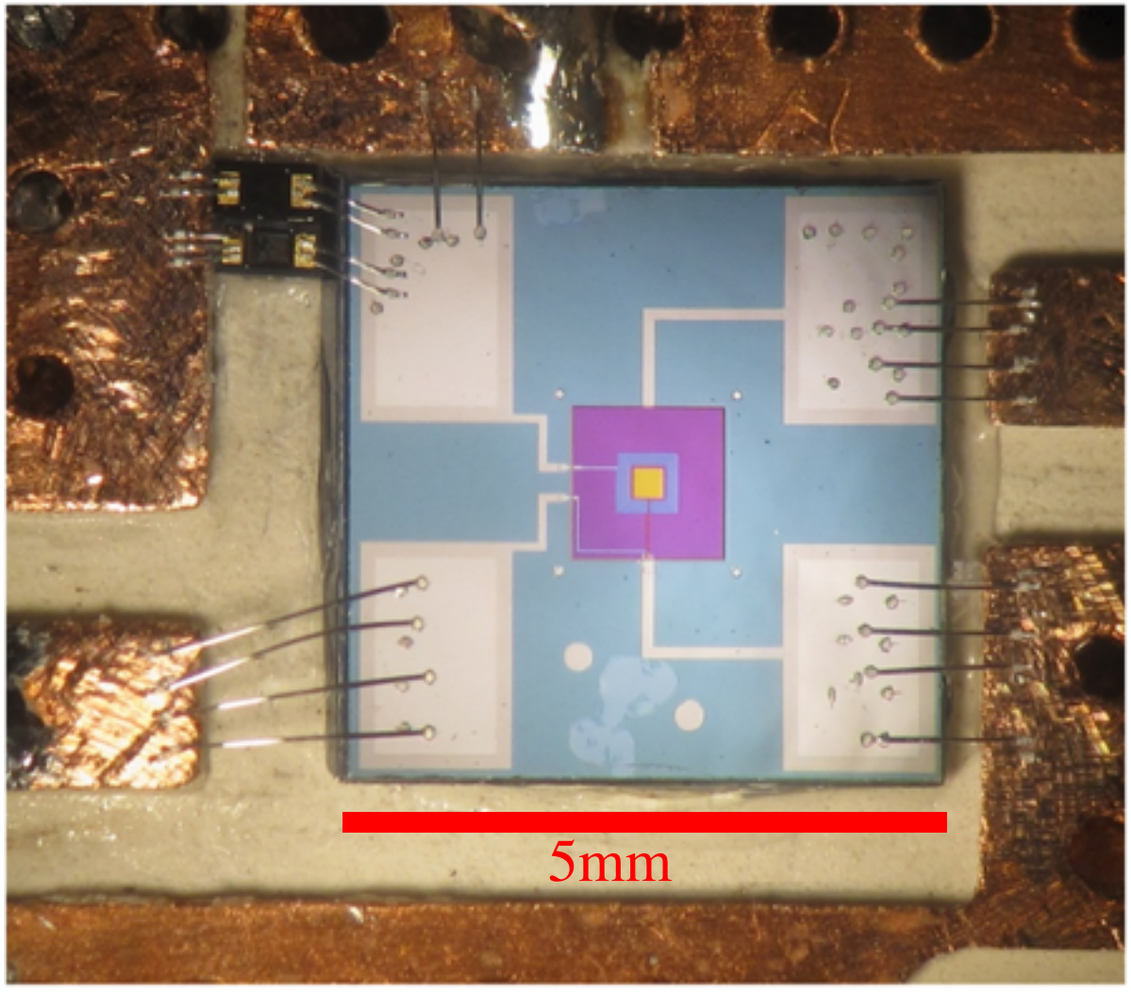
The search speed is quadratic in 1/Ts

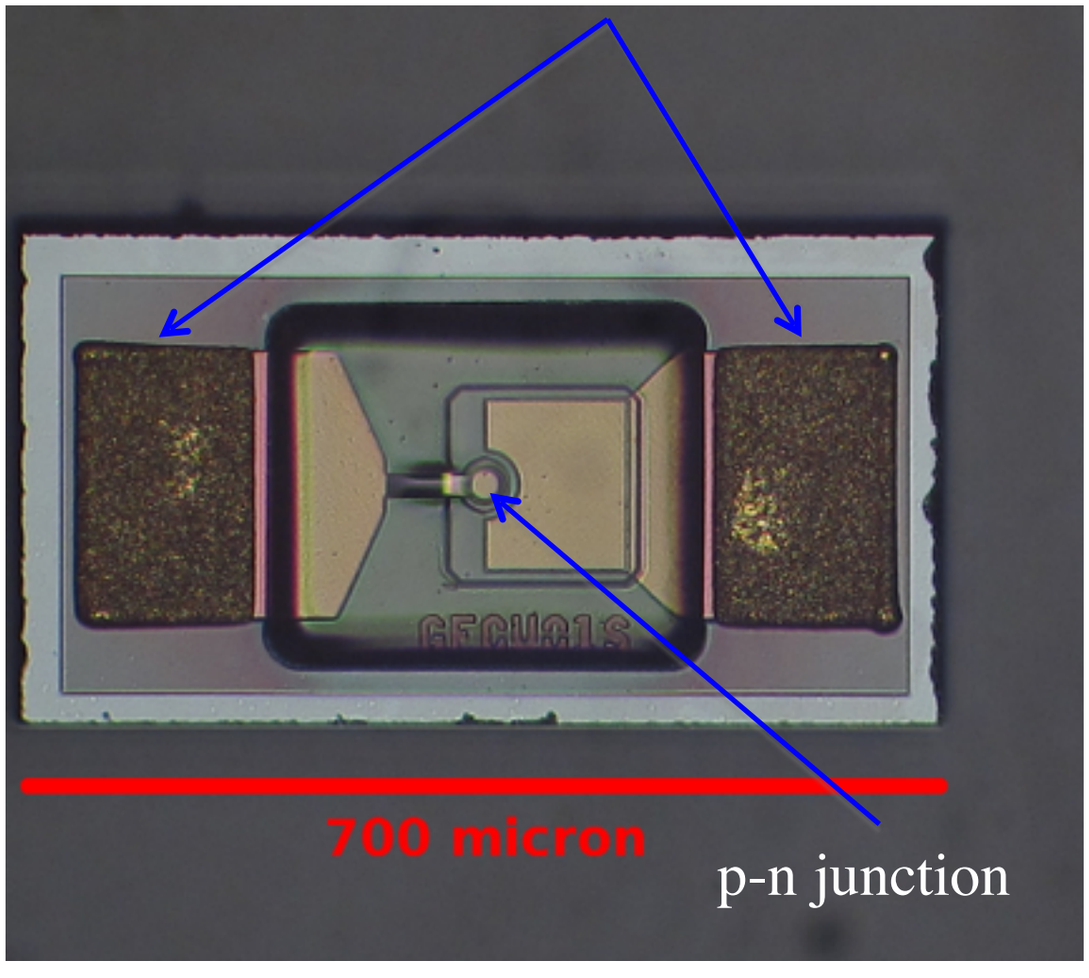


Scaling Laws	
$\frac{d\nu}{dt} \propto B^4V^2 \cdot \frac{1}{T_S^2}$	$g_\gamma^2 \propto \left(B^2V \cdot \frac{1}{T_S}\right)^{-1}$
For fixed model g^2	For fixed scan rate $\frac{d\nu}{dt}$

RF-cavity experiments obey the radiometer equation

ADMX hardware:
microstrip SQUID amplifiers with varactor tuning





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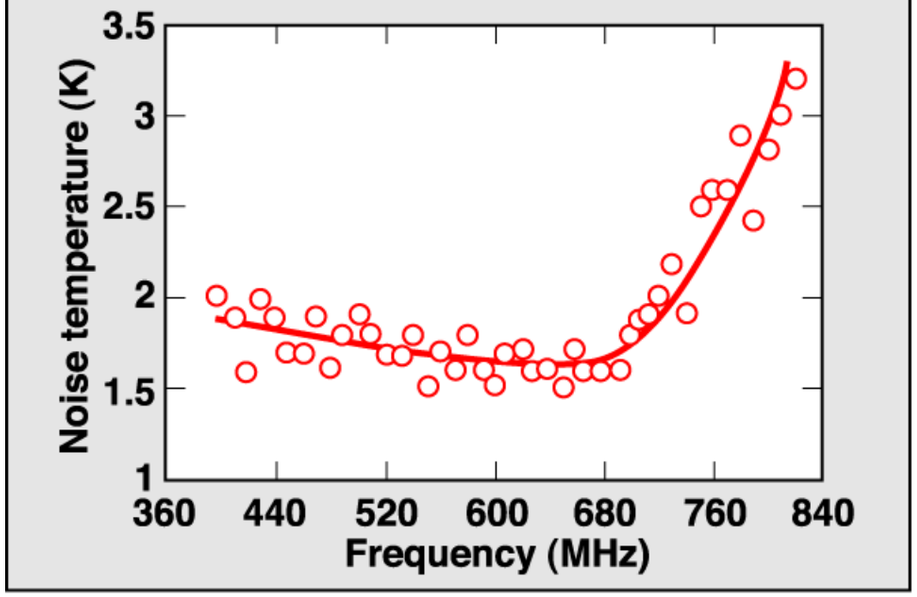
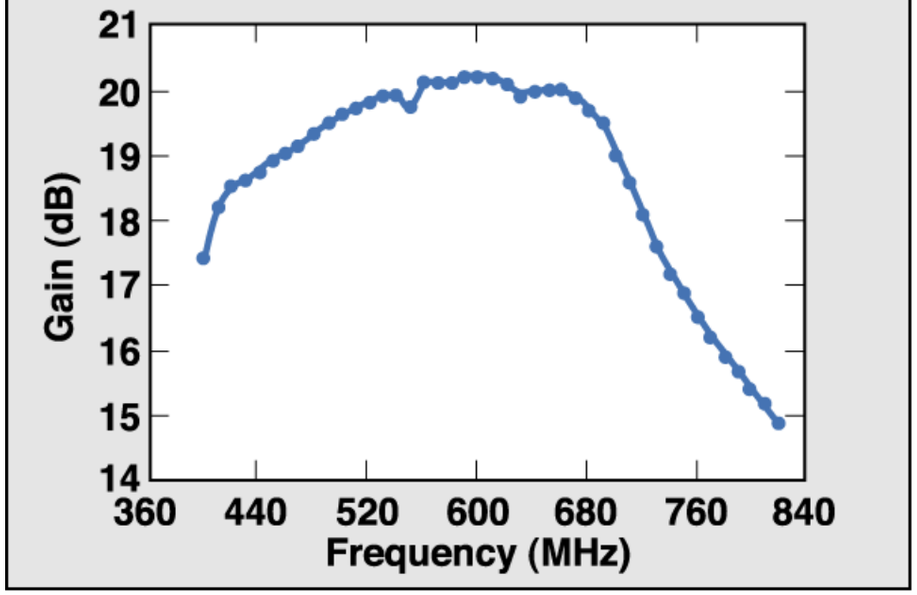
Noise Performance

Noise Temperature

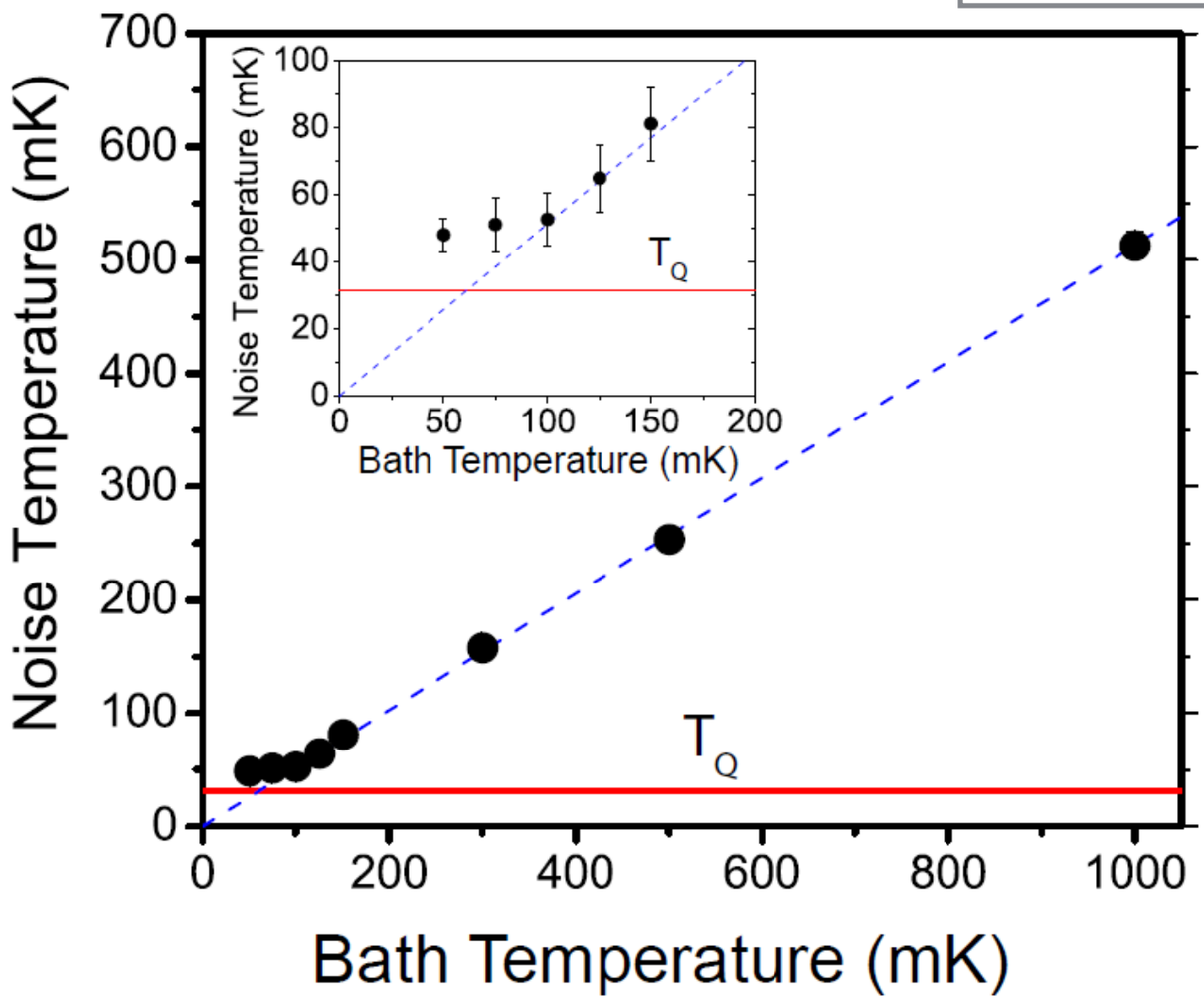


Gain

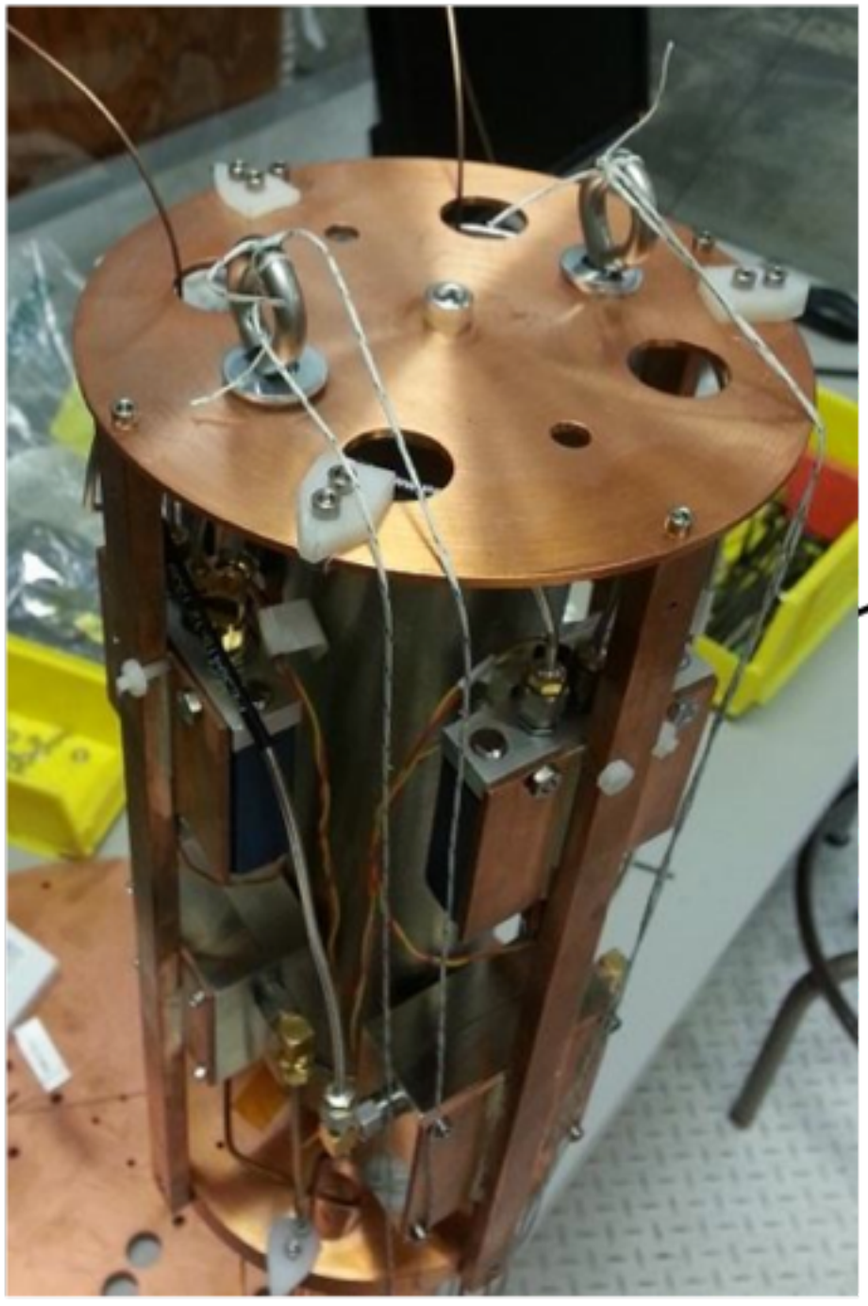


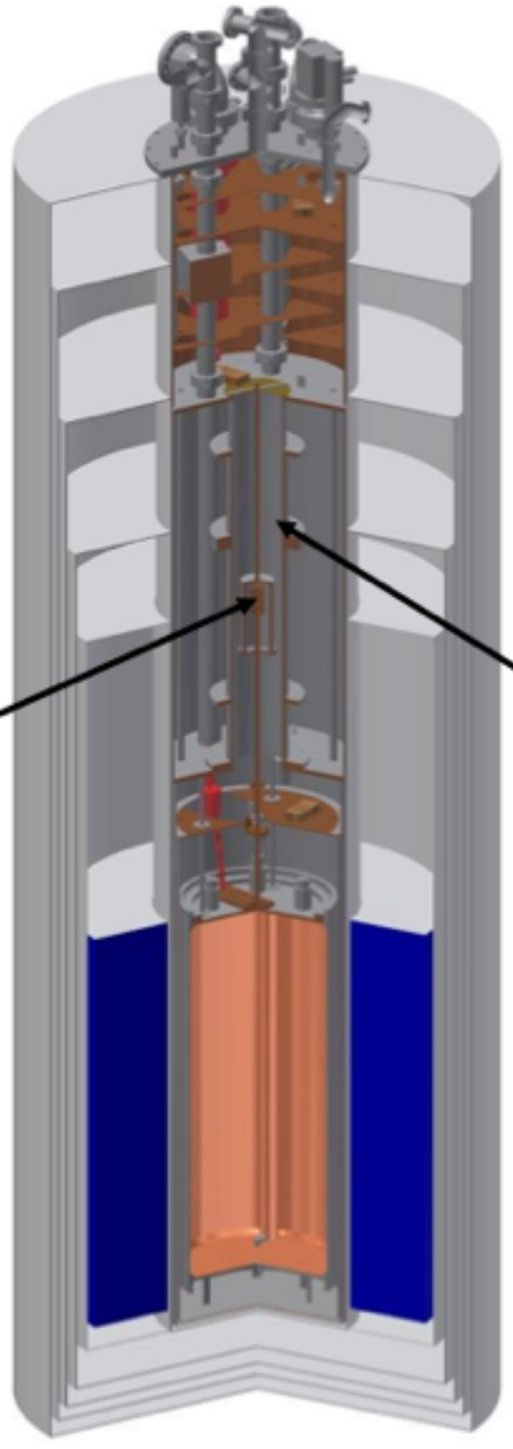
- **Currently HFET amplifiers (Heterojunction Field-Effect Transistor)**
  - **A.k.a. HEMT™ (High Electron Mobility Transistor)**
  - **Workhorse of radio astronomy, military communications, etc.**

$$\left(\frac{1.5}{0.06}\right)^2 = 625$$



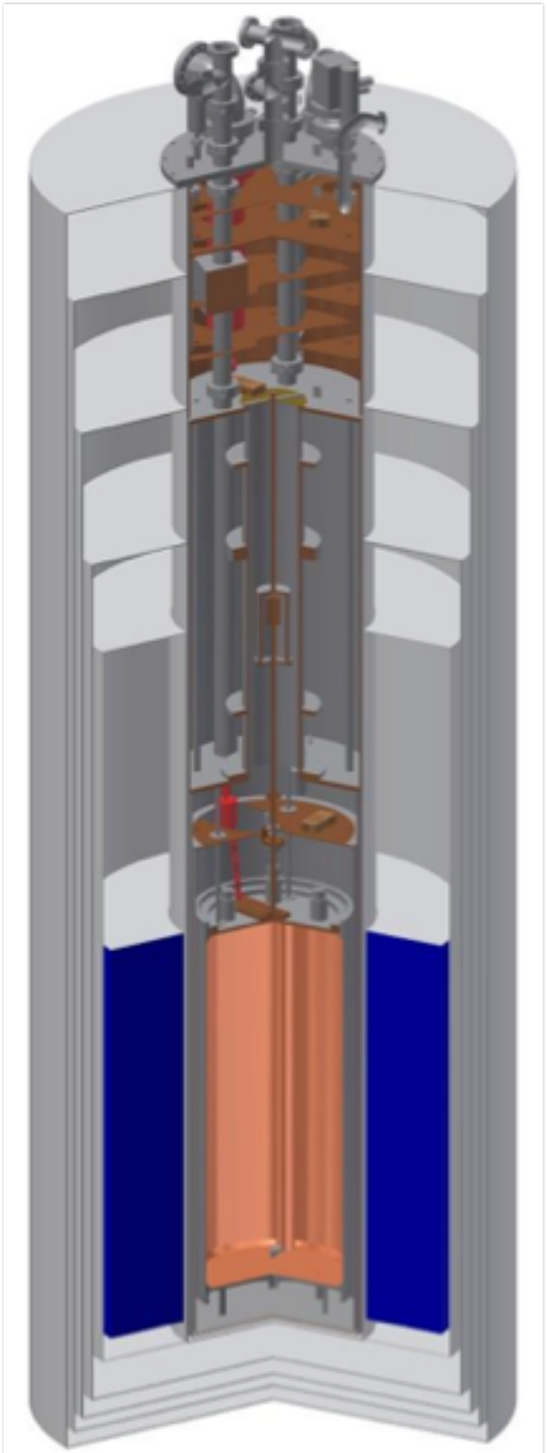
Quantum-electronics in a bucking coil

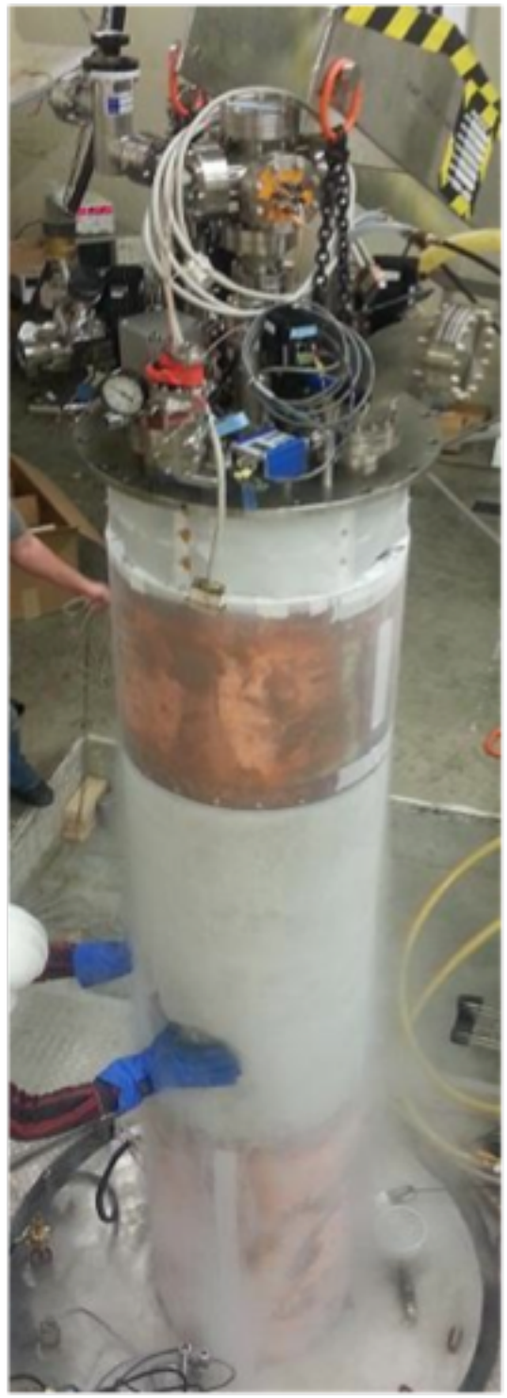




ADMX insert going into and out the magnet bore

Science, Nov. 2013, 552 - 555





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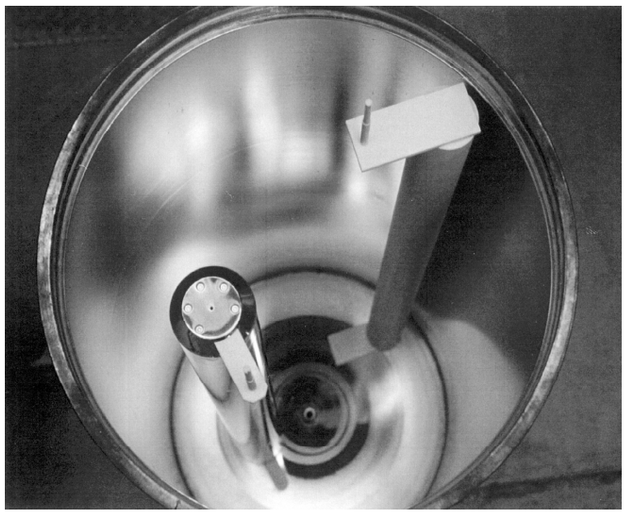
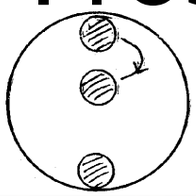
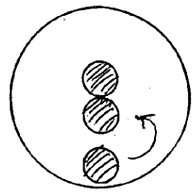
Probing higher axion masses - Cavities

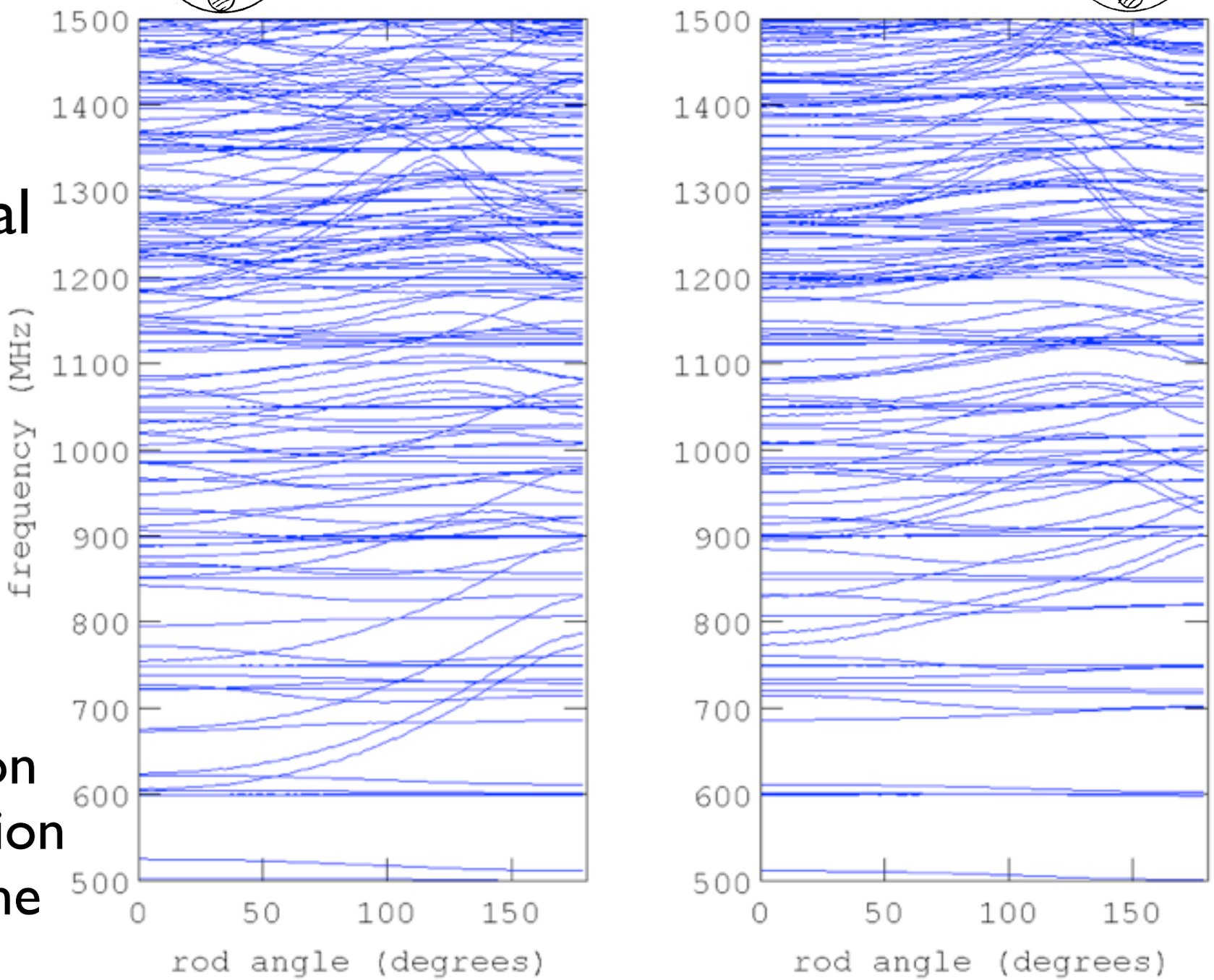
The volume of the magnet dictates the total cavity volume.



For same conversion power at higher axion mass, either combine multiple cavities or exploit higher order modes of the big one.







Sheffield ANSYS simulation of lowest 200 modes of the current ADMX resonator.

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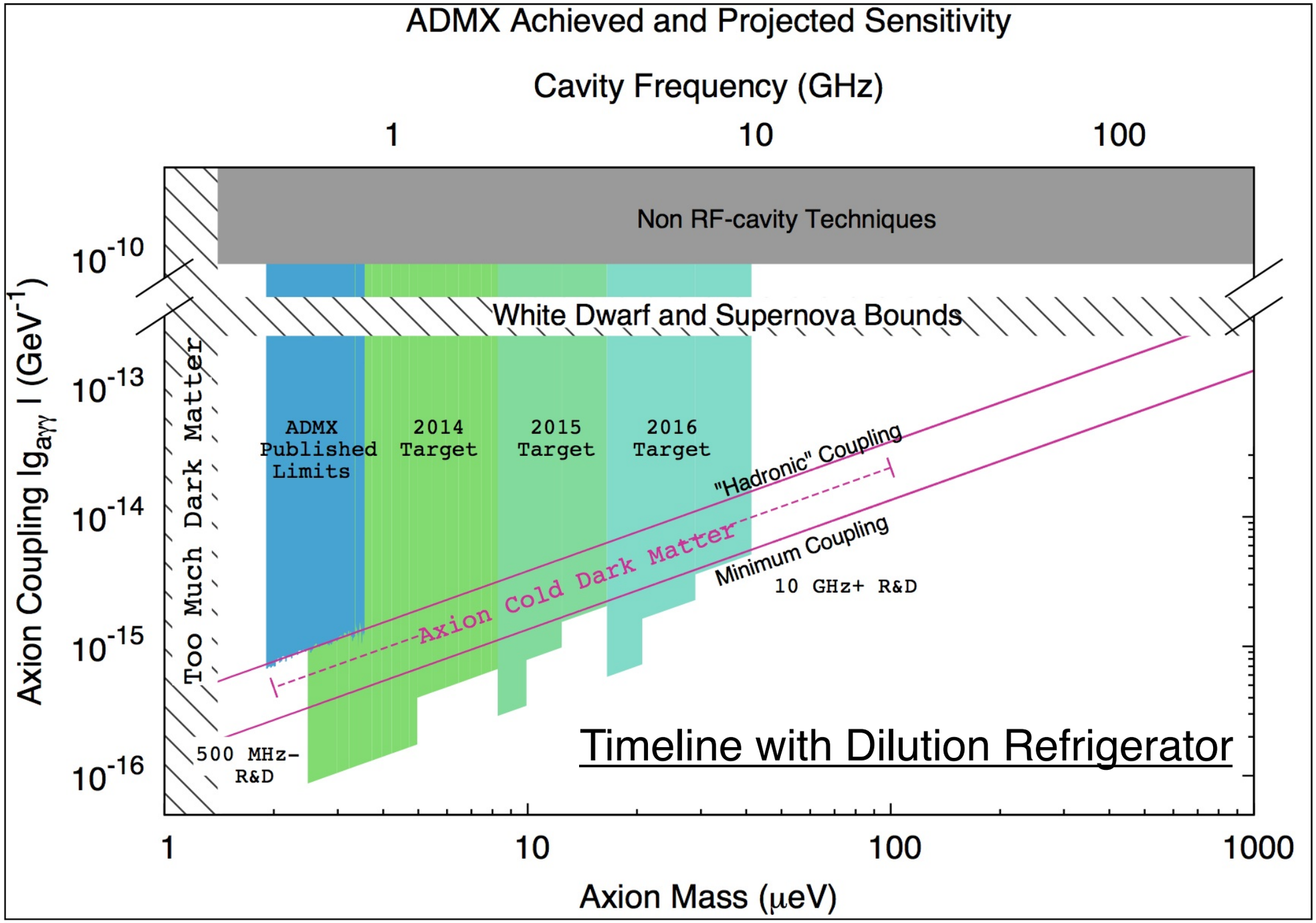

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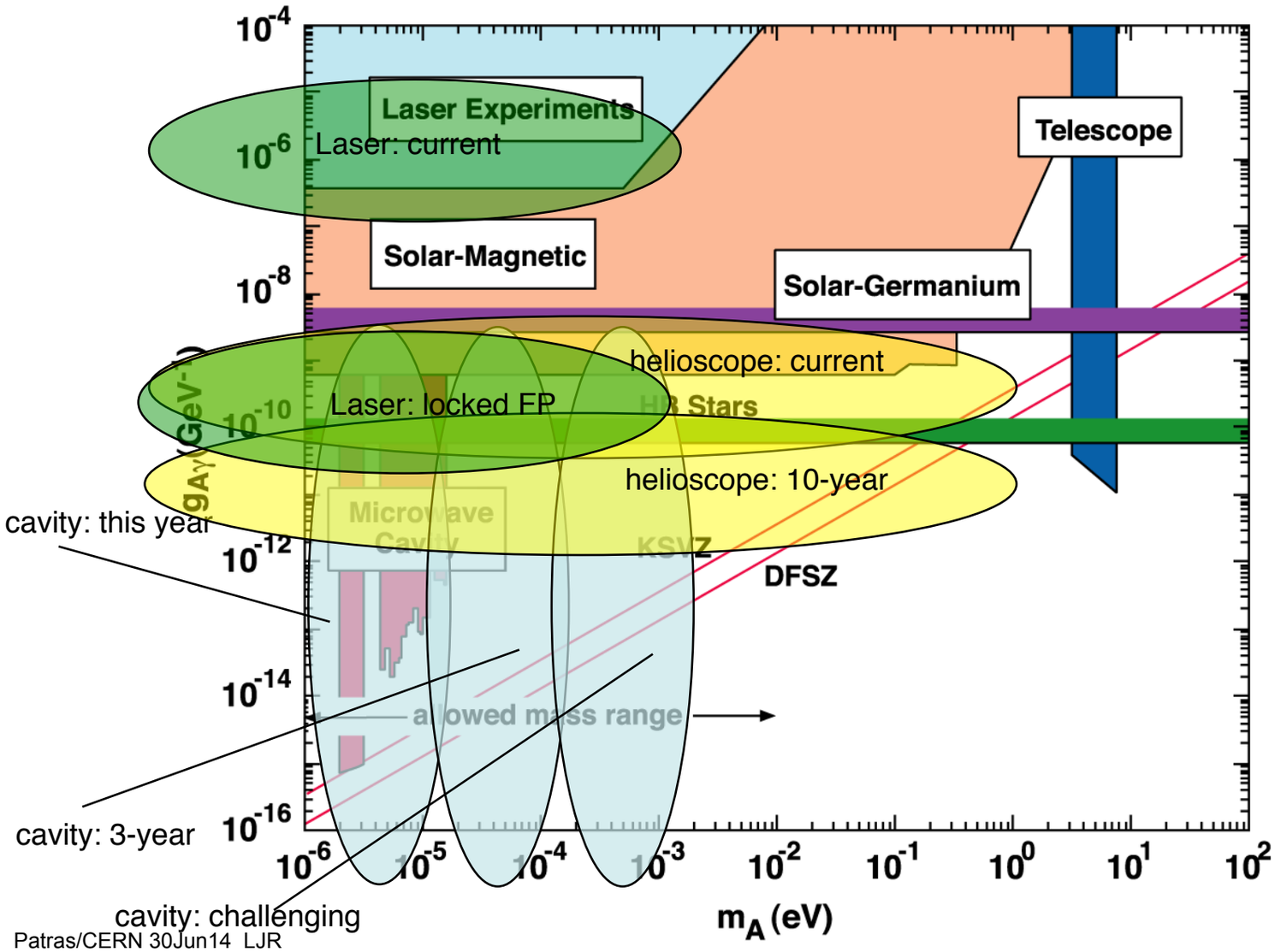
ADMX in the context of other key search technologies



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Conclusions

Axions are a good dark matter candidate. To me, just as well motivated as WIMPs.

The Higgs discovery lends credibility to other symmetry breaking physics such as the Peccei-Quinn mechanism that gives axions

The U.S. agencies agree; DOE/NSF just selected ADMX as one of three ‘Gen2’ dark matter search experiments for U.S. funding.

ADMX II is currently being commissioned with a dilution fridge and SQUID electronics.