Preliminary Measurements in Search for 0.1 meV Axions and Hidden Photons using Copper Resonant Cavities

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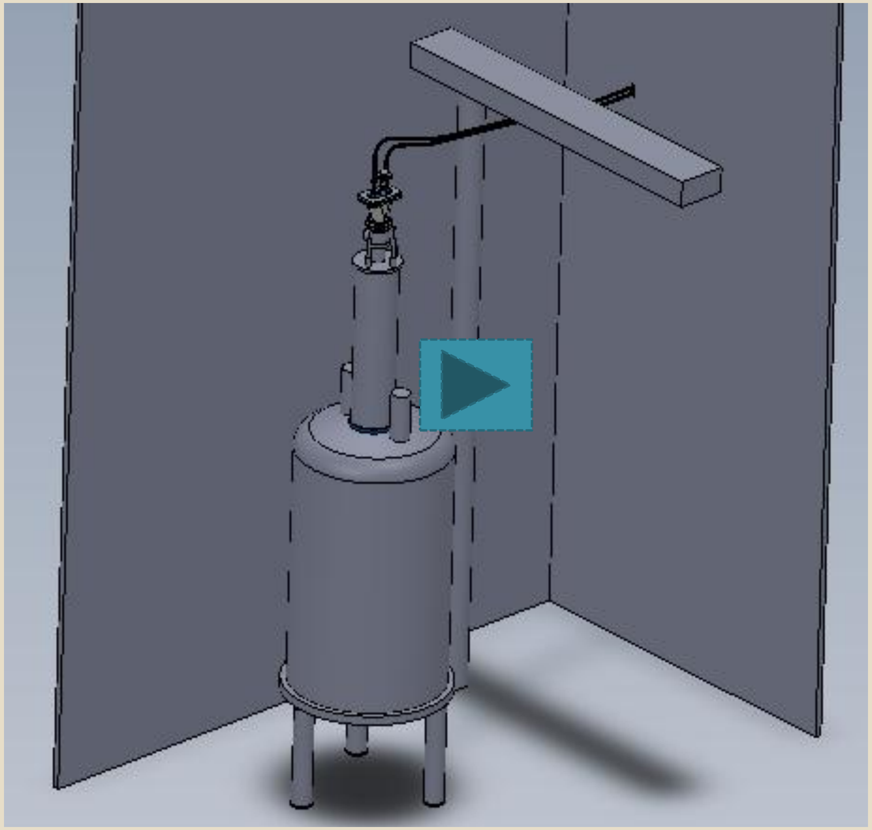
Overview of experiment

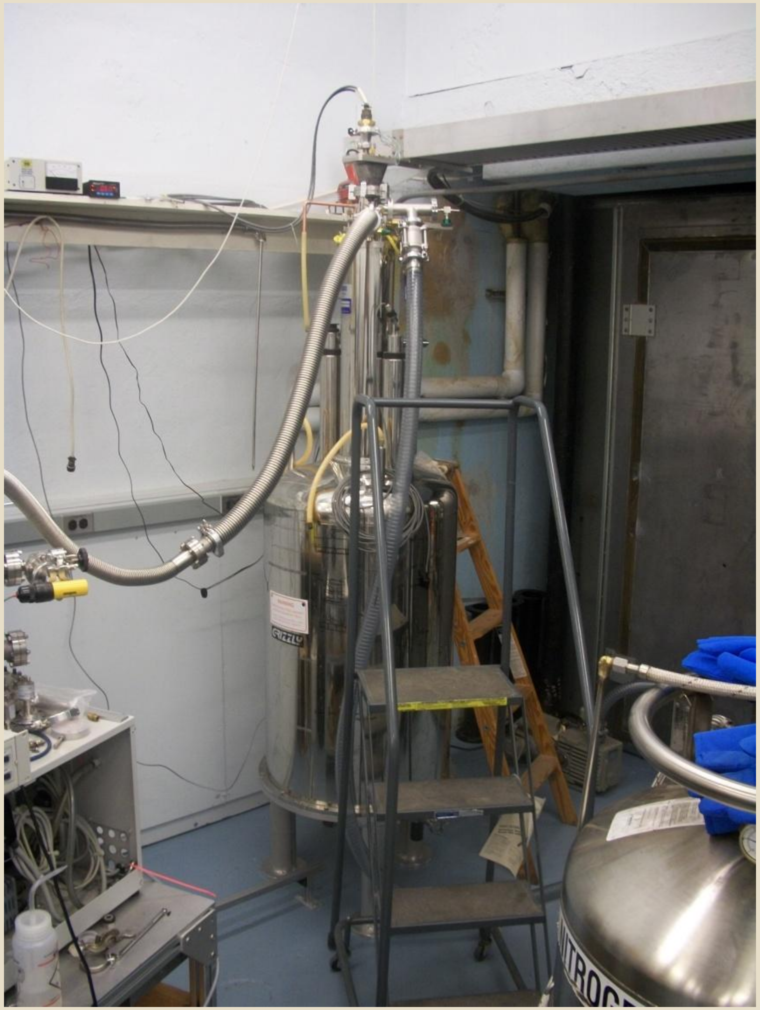
- LNB ($g=10^{-6}$/GeV) and HSP ($\chi=10^{-7}$) near 0.1 meV
- Generation – regeneration experiment with 2 Cu resonant cavities inside 7 Tesla magnet.
- MW 34 GHz magnicon at Yale.



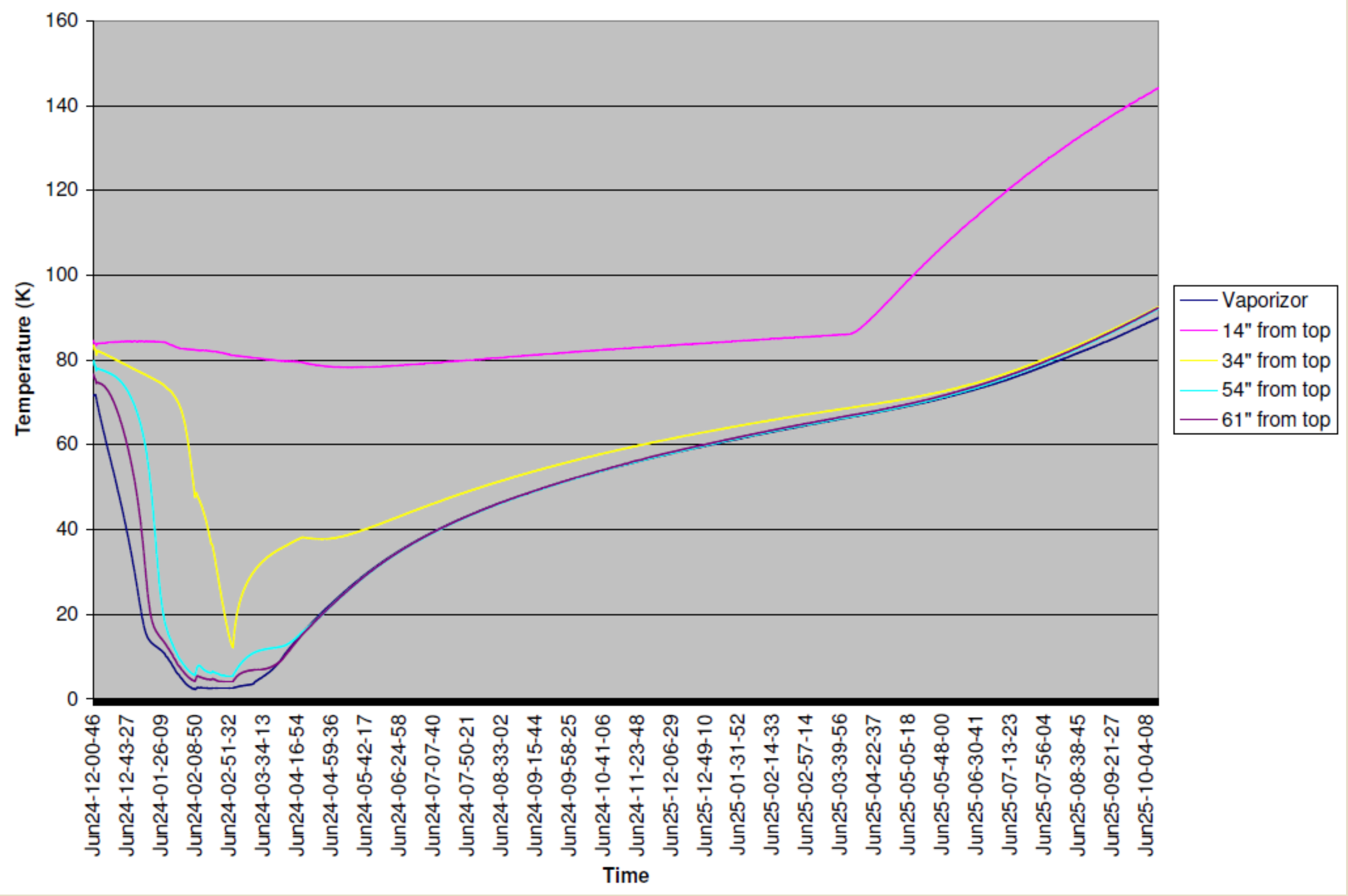
Drawing courtesty of Will Emmet

Cryostat and magnet

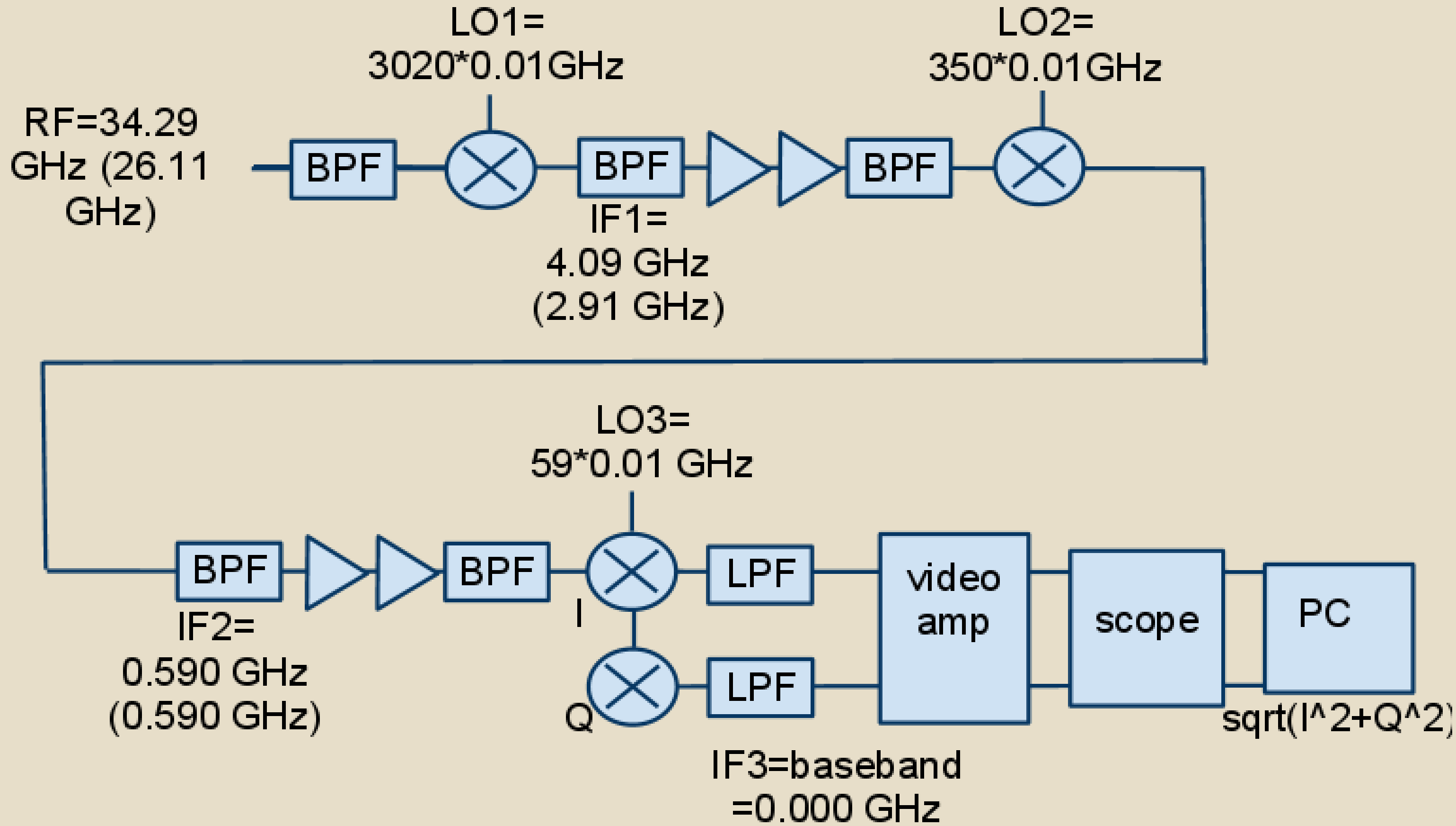
- 7 Tesla cryomagnet, 89 mm warm bore.
- Liquid He flow cryostat extending into magnet bore. Sample region in cold He vapor, at center of magnetic field.



Cryostat temperatures

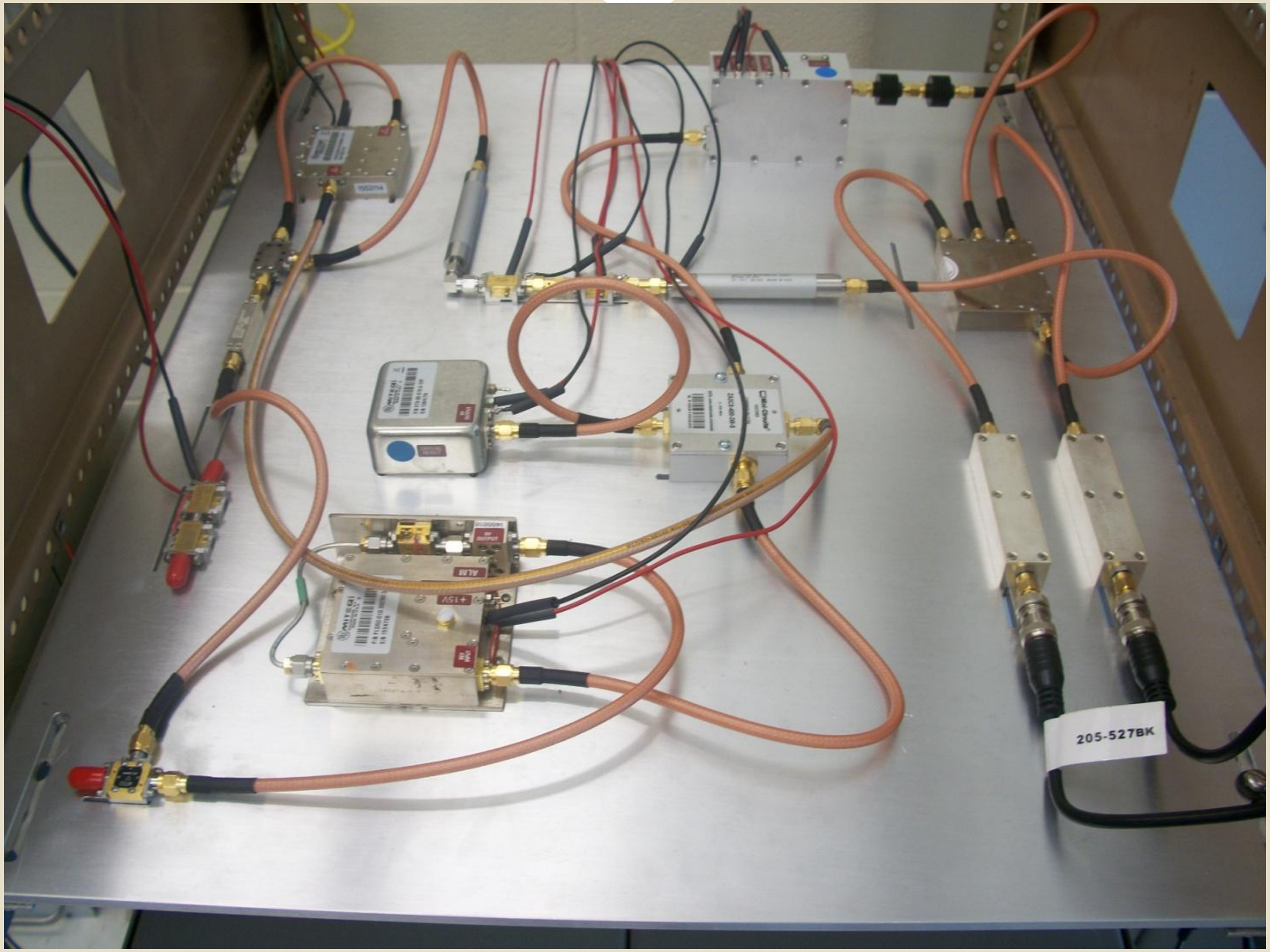


Receiver



W. Guinon, private communication

Receiver layout

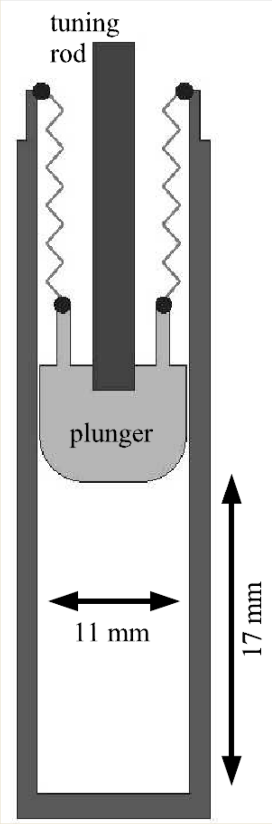


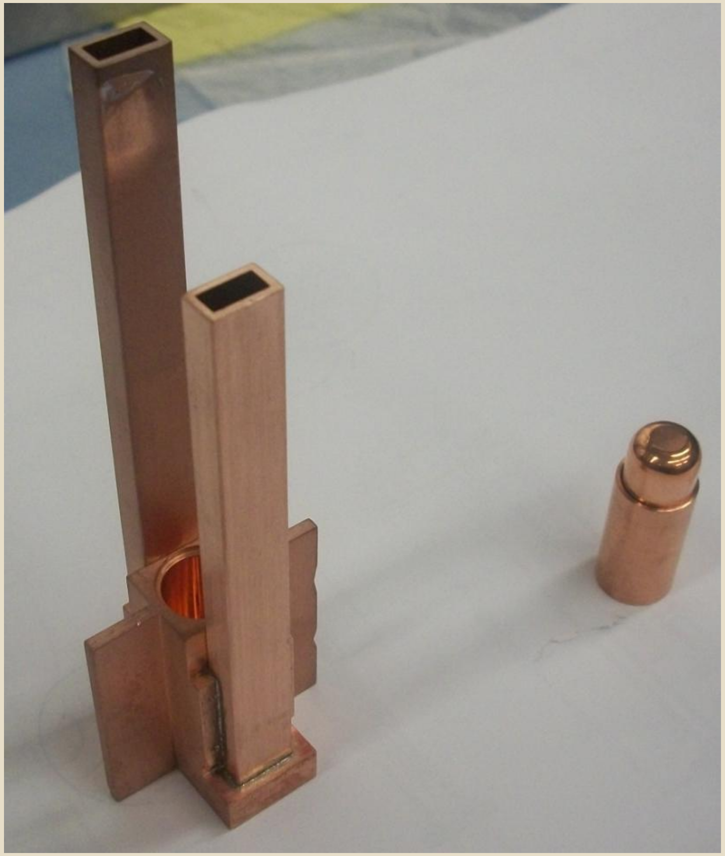
Receiver status

- Room temperature components were assembled and powered two weeks ago.
  - 4 GHz amplifier chain had been oscillating due to loose ground lug. Qualitative performance now looks good. More tests pending.
  - 590 MHz amplifiers are working and have noise power less than 10^(-11) Watts per MHz between 560 and 620 MHz.
  - Oscillators working well.
- Cryogenic HEMT amplifier has been cooled to 77 K and tested.
  - DC specs match those of supplier at 300 K and 20 K.
  - Broadband noise power at 77 K was undetectable with Schottky diode (sensitivity 0.5 mV/μW).

Signal Cavity

- TE011 mode.
- Q ~ $1.5x10^4$
- Cooled to <10 K.

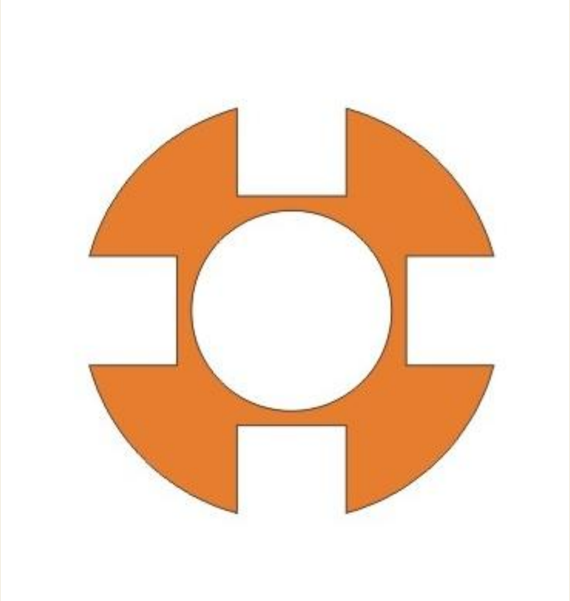




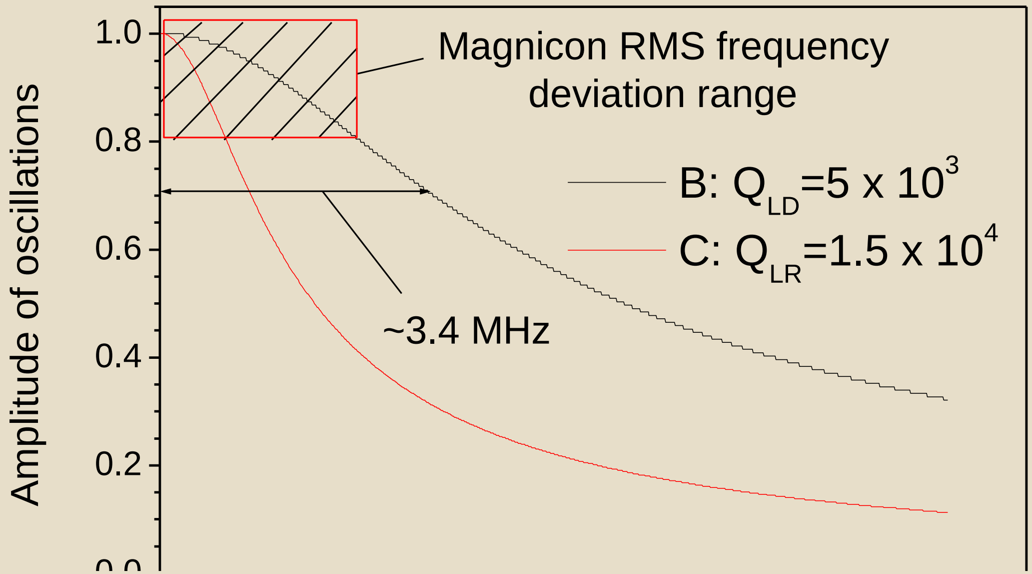
Braze oven

Drive Cavity

- TE011 mode.
- Q ~ 5000
- Dissipates 10 W average power
- Water cooled.
- 4 pressure points for initial tuning.



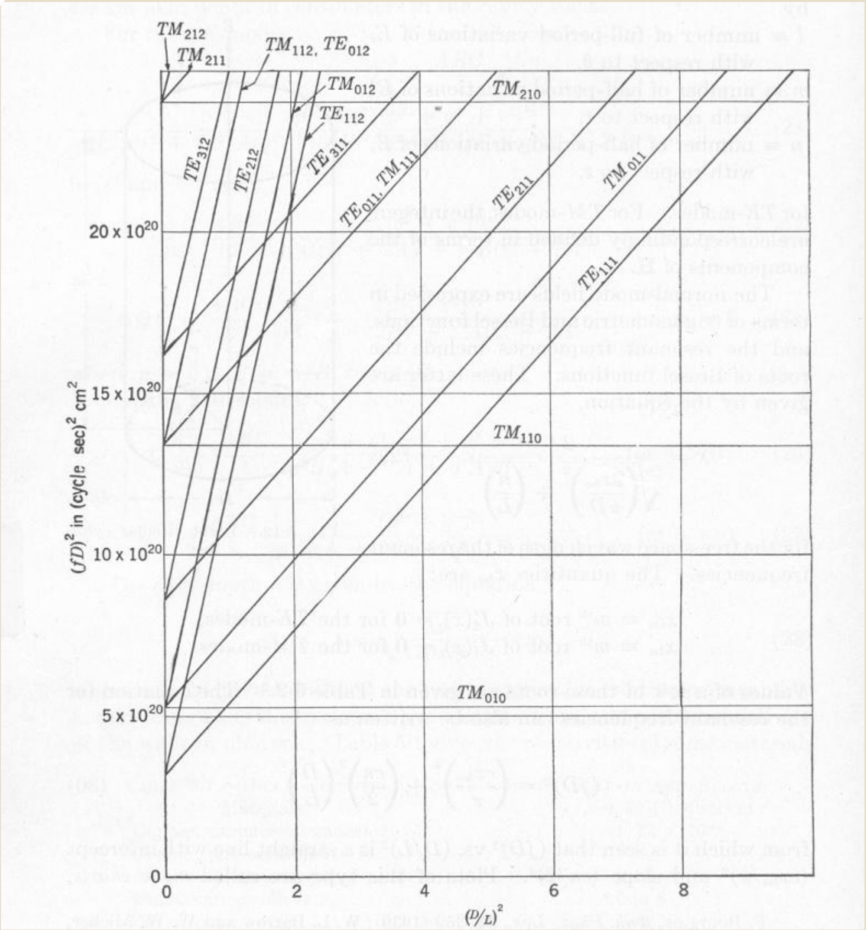
Magnicon intrapulse phase deviations



G.M.Kazakevich,et al.,Nucl. Instr.and Meth.A(2010), doi:10.1016/j.nima.2010.05.051

Signal cavity – sweep range for halo axions

- Tuning plunger can move +/- 2 mm.
- For cylindrical cavity TE011 mode:
  - +2 mm --> 33.5 GHz = 0.137 meV
  - -2 mm --> 35 GHz = 0.143 meV.
- g = 10^{-7}/GeV assuming S/N ~ 1. Integration time determines additional sensitivity.



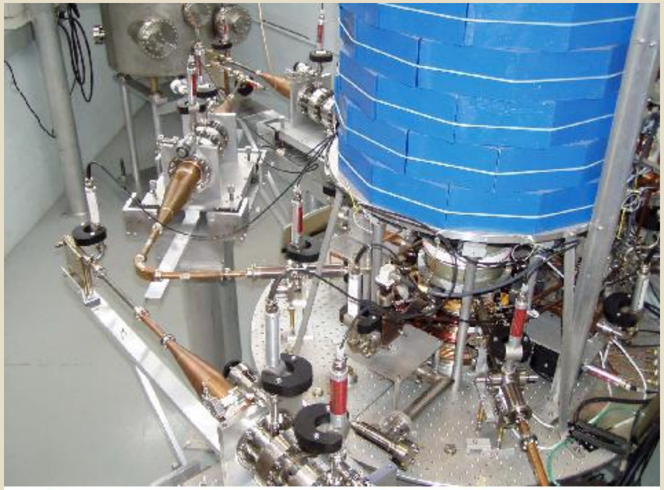
C. G. Montgomery, Technique of Microwave Measurements,
New York and London McGraw-Hill Book Company, Inc., p. 298, 1947.

Summary

- Equipment testing is going well:
  - Cryostat is cold. Tests are continuing.
  - Cryogenic amplifier has been cooled and tested outside the cryostat.
  - Room temperature receiver chain is assembled and powered. Specs look good.
  - Noise power of receiver parts has been hard to measure – a good problem.
- Next steps:
  - Finish machining and brazing cavities, get signal out of cryostat.
  - Drill hole in shielded room for waveguide.
  - Set up trigger and take data.

Auxiliary slides

34 GHz microwave source



•Output: 10 MW, 1μs pulses at 10 Hz. Bandwidth=1 MHz.

•500 kV, 215 A e- beam transverse deflection system:

- •Drive cavity (11.4 GHz), 3 gain cavities, and two final cavities.
- •Transverse beam momentum is transferred to RF fields at high efficiency.

O. A. Nezhevenko et al., IEEE Transactions on Plasma Science, 0093-3813/04, 2004.

Photos courtesy of M. Lapointe

Expected Signal Power

For g=2.5e-6/GeV

$$\Pi_{\gamma \to \phi} \approx \frac{1}{4}(gBL)^2,$$

or $\Pi = 10^{-15}$ for B=8 T and L=10 cm.

Probability Π^2 yields the expected signal power:

$$P_{LNB} = P_{beam}\Pi^2 Q_1 Q_2.$$

T(K)	Q_1	Q_2	P_{LNB}	N_{phot} at 34 GHz
300	1.5e4	2.e3	10^{-21} W	66 phot/s
40	9.e4	1.2e4	10^{-20} W	660 phot/s

Expected Noise Power

Friis' formula: $T_N = T_1 + \frac{T_2}{G_1} + \frac{T_3 - 1}{G_1 G_2} \cdots$

=> $T_N \approx 3(300\text{K}) + \frac{300\text{K}}{1000.} + \frac{300\text{K}}{1000.*10000.} + \cdots \approx 900\text{K}.$

Assuming a flat thermal noise spectrum,

$P_N = k_B T_N B$ = (1.38e-23 J/K)(900 K)(10^6 Hz) =10^{-14} W

With gating (x10^{-5}), P_N~10^{-19} W, or 5300 photons/s at 34 GHz.

From $\frac{N_S t}{\sqrt{N_B t}} \equiv 5$ where N_S=66 Hz and N_B=5300 Hz,

=> t=30 s at T=300K (or 0.3 s at T=40K).