Microwave Cavity Search for 0.1 meV Axions

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PATRAS Workshop
DESY
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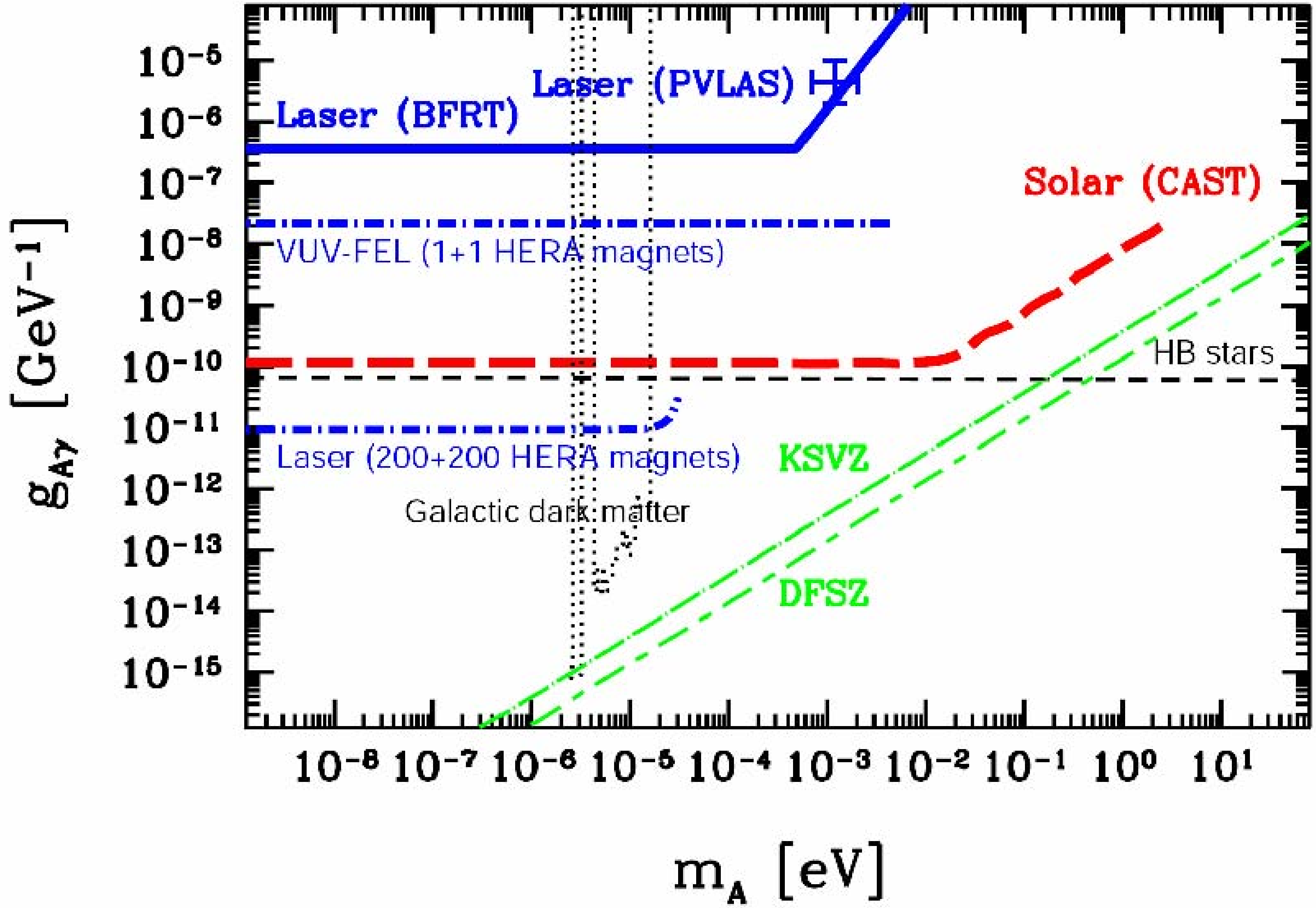
Overview

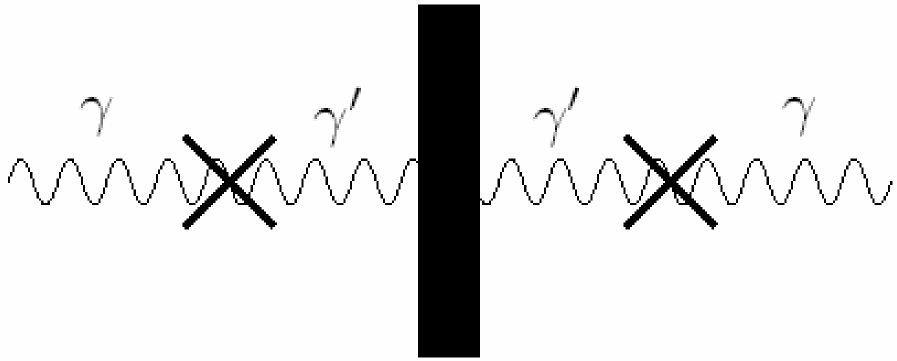
- “Light shining through walls” experiment: Simultaneous searches for
  - 0.1 meV axions
  - 0.1 meV hidden sector photons
- Status of experiment
- Plans for initial bench tests

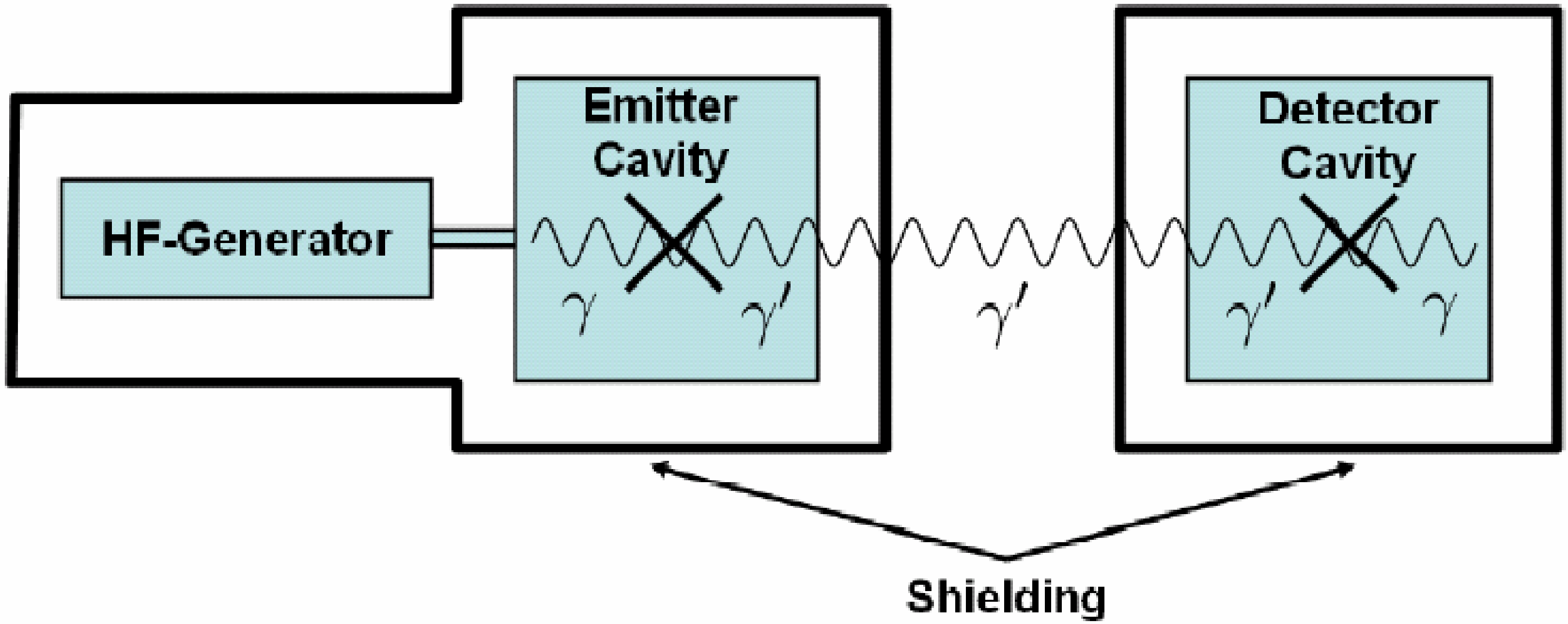
Axion Searches



Ringwald, 2006 J. Phys.: Conf. Ser. 39 197

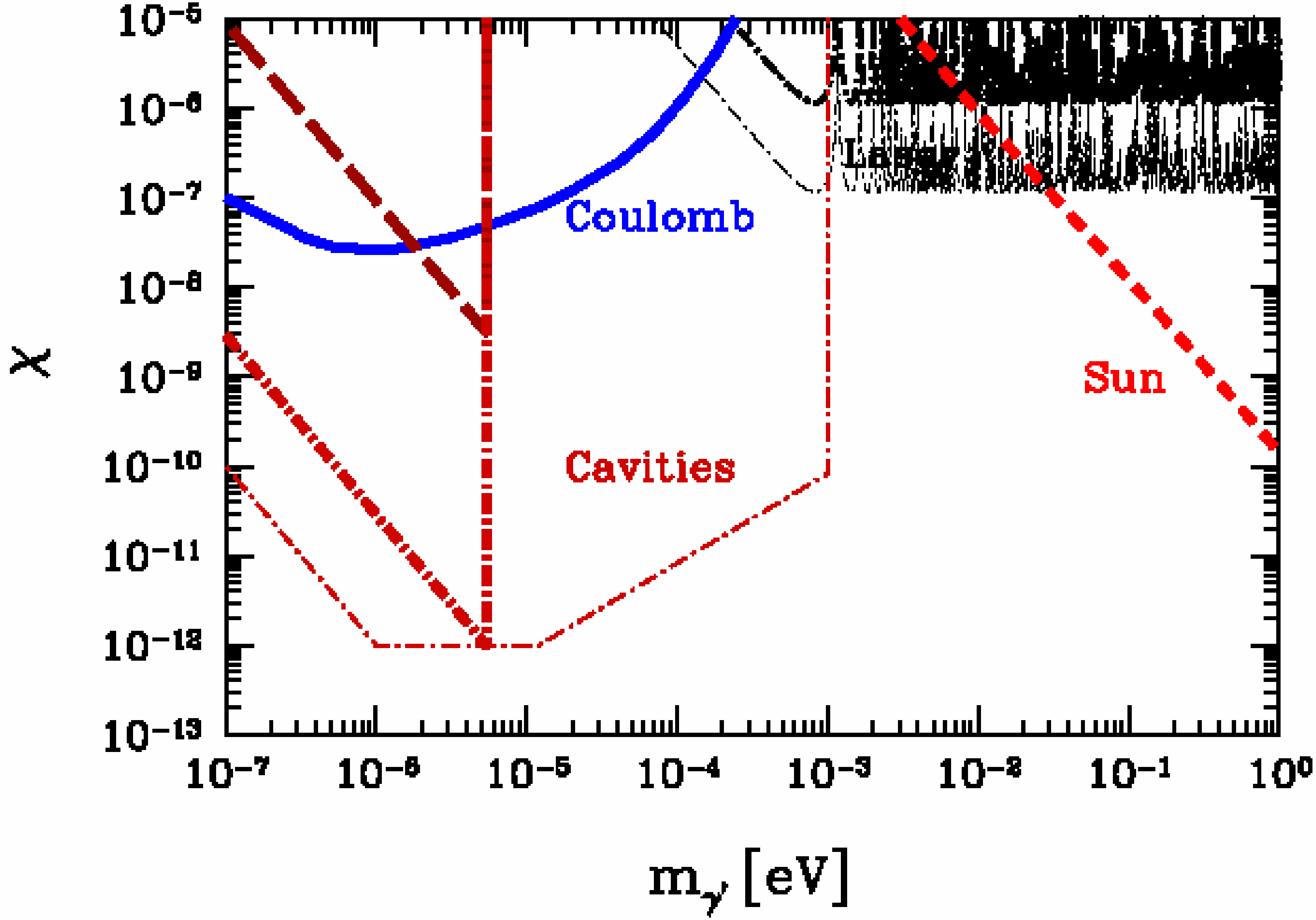
Photon-Paraphoton Oscillation





Jaeckel and Ringwald, Phys. Lett. B 659:509-514, 2008.

Limits on Photon-Paraphoton Mixing Parameter χ



Jaeckel and Ringwald, Phys. Lett. B 659:509-514, 2008.

34 GHz Microwave Source

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

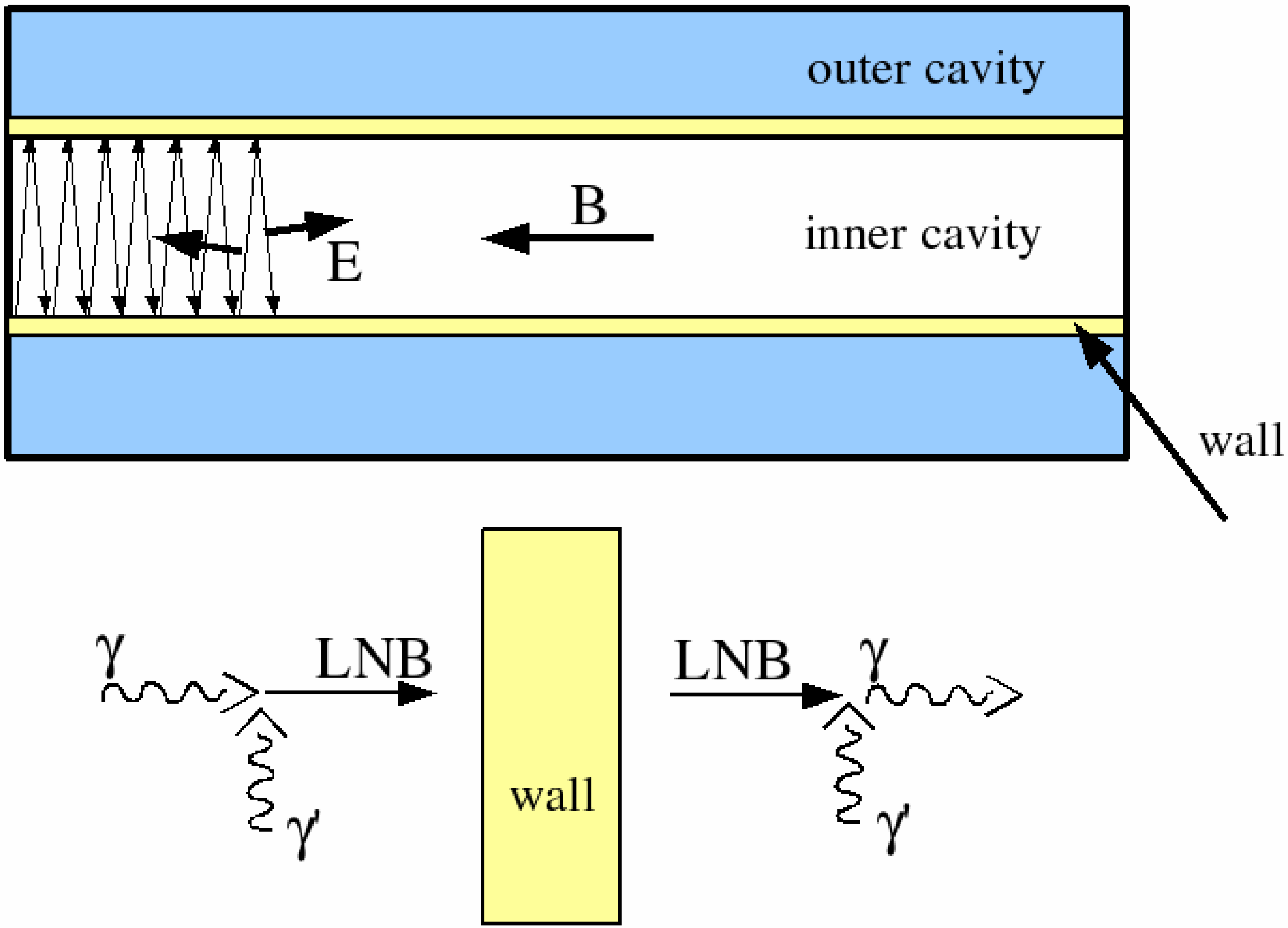
•500 kV, 215 A e- beam transverse deflection system:

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

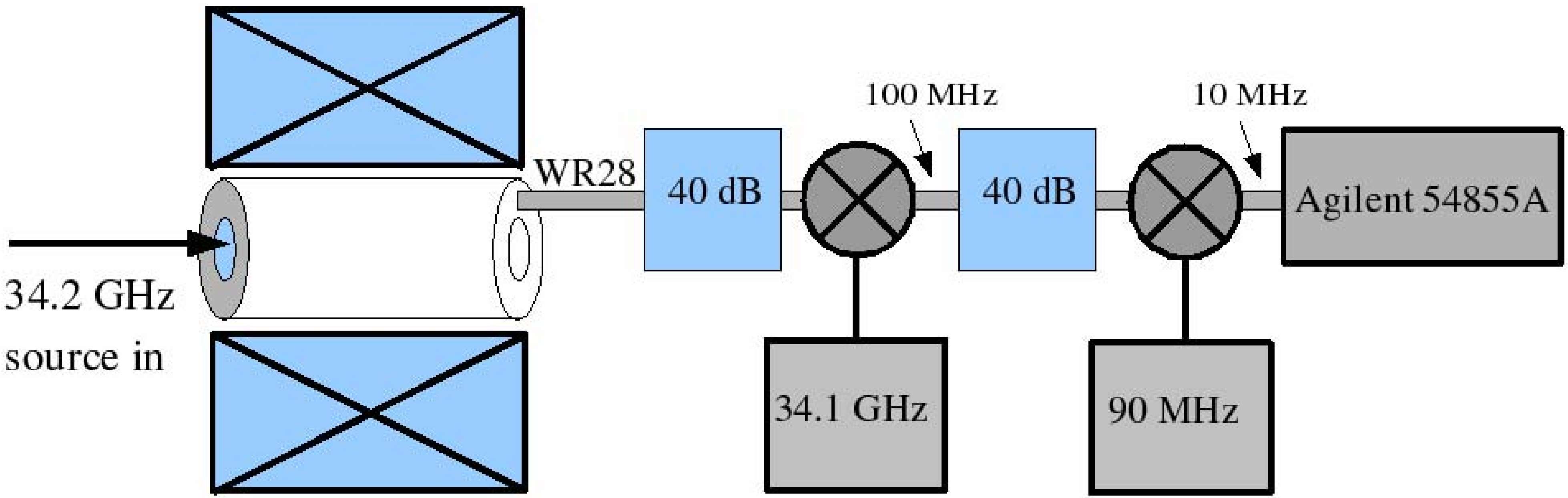
O. A. Nezhevenko et al., IEEE Transactions on Plasma Science, 0093-3813/04, 2004.

Photos courtesy of M. Lapointe

Coaxial Cavities



Experiment



WR28
40 dB
100 MHz
40 dB
10 MHz
Agilent 54855A
34.2 GHz
source in
34.1 GHz
90 MHz

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,

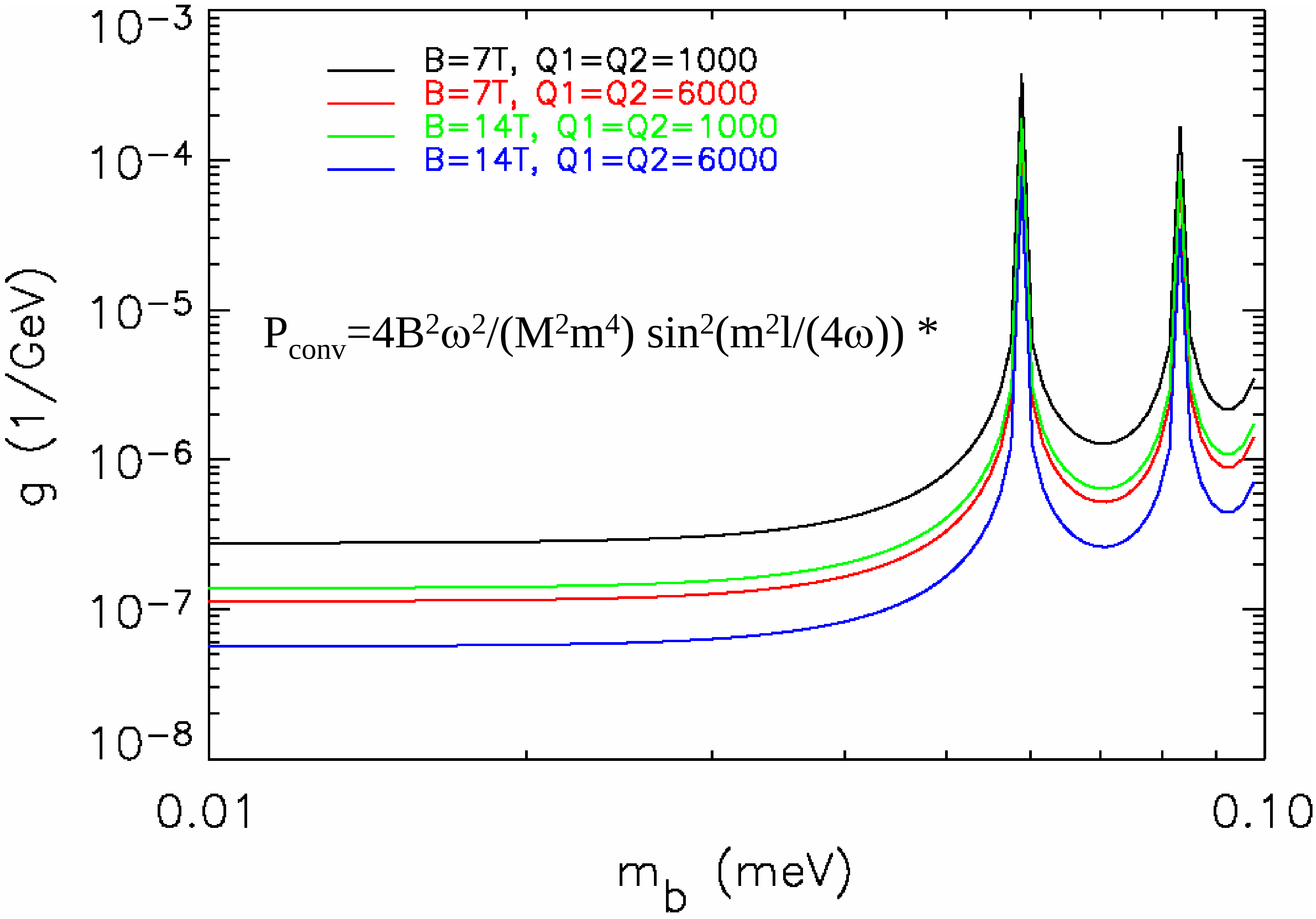
$P_N = k_B T_N B = (1.38\text{e-}23 \text{ J/K})(900 \text{ K})(10^6 \text{ Hz}) = 10^{-14} \text{ W}$

With gating (x10^{-5}), $P_N \sim 10^{-19}$ 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,

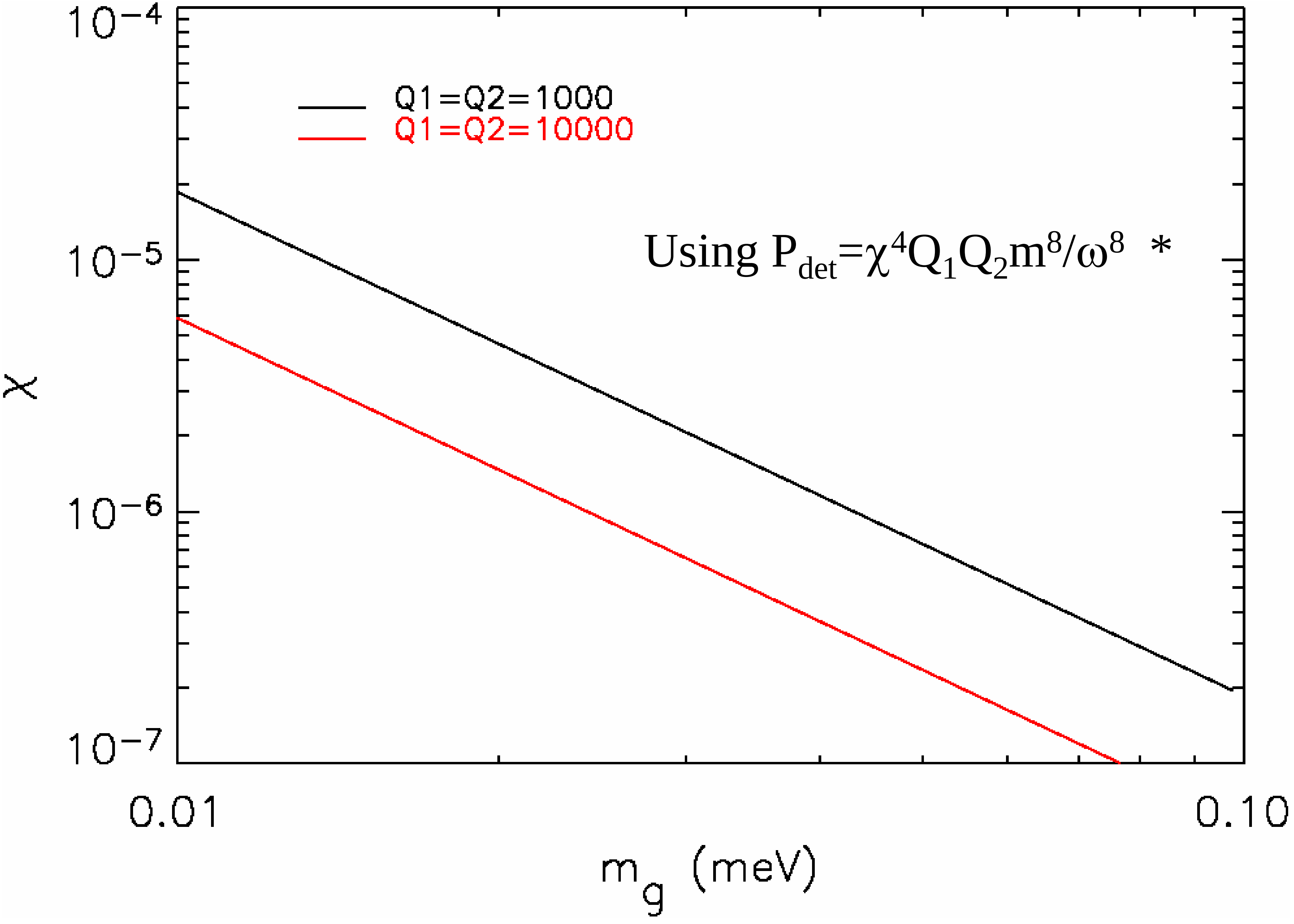
=> t=30 s at T=300K (or 0.3 s at T=40K).

5σ Exclusion



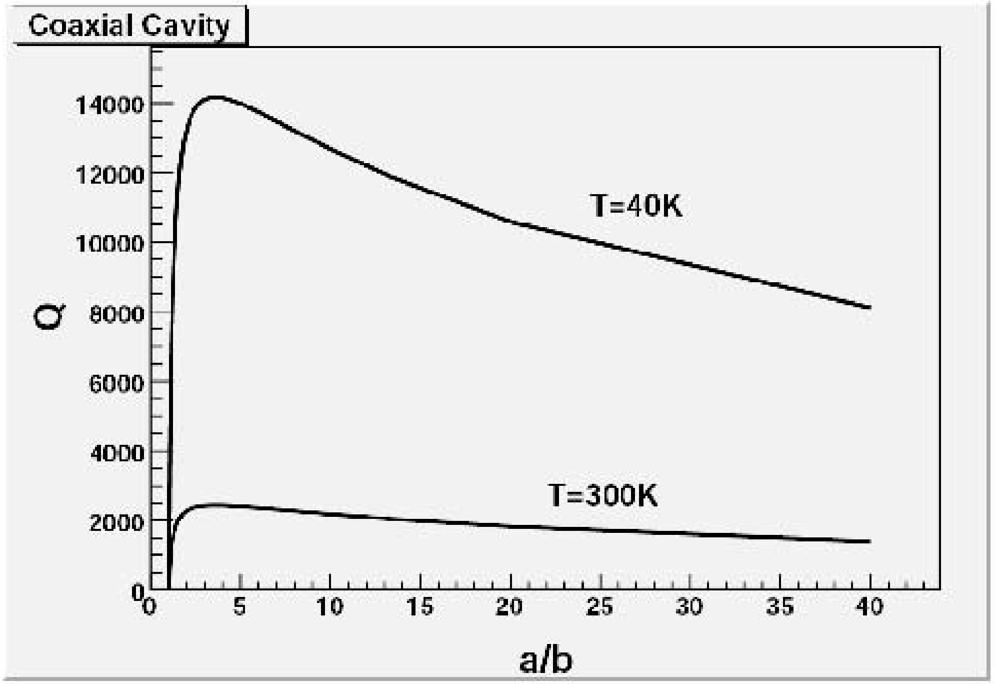
*Cameron et al., Phys. Rev. D (47)9, 1993

5σ Exclusion

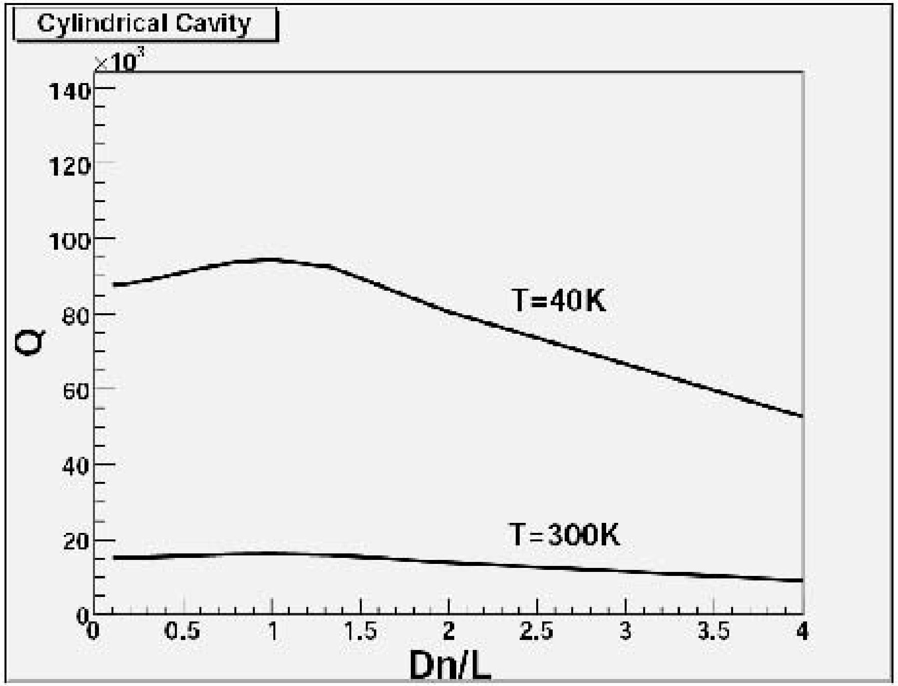


* Jaeckel and Ringwald, Phys. Lett. B 659 (2008)

Cavity Q-factors



TEM$_{001}$



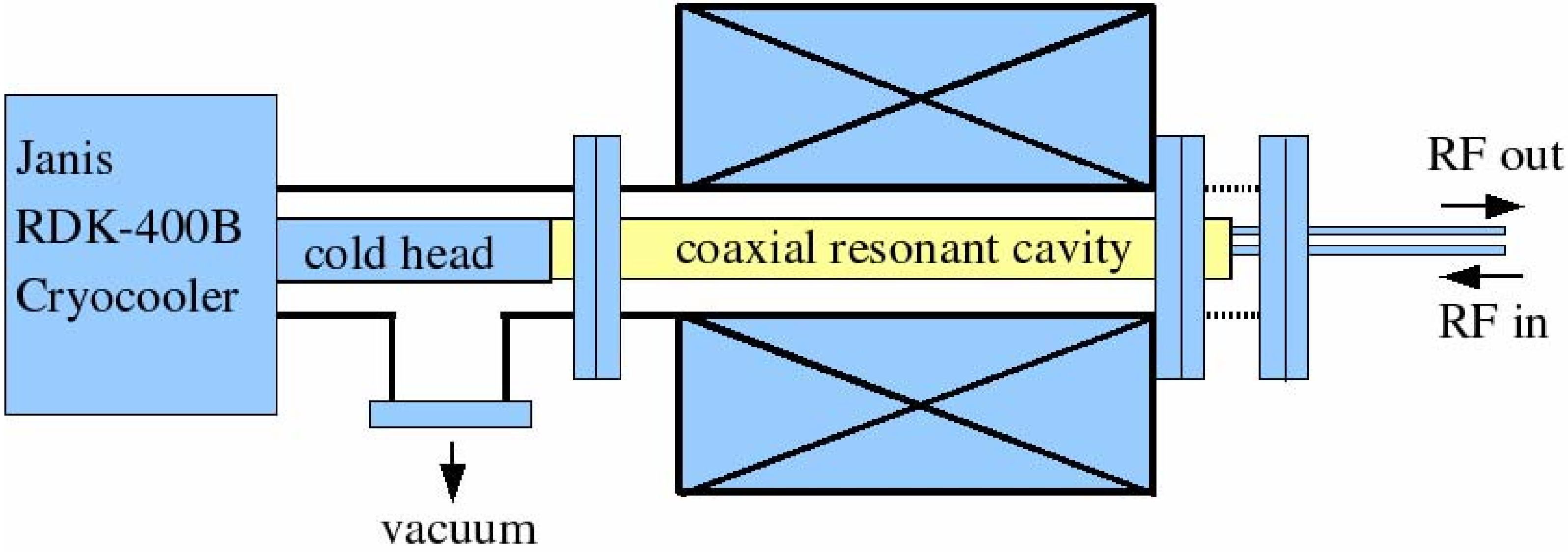
TE$_{01n}$

Using $\delta = \sqrt{2/(\omega\sigma\mu)}$, with $\rho=\rho(T)$, and $\delta \to \delta(\omega\tau)^{1/2}$ for T=40K.

(λ/δ_{300K}=2.5e4; λ/δ_{40K}=1.4e5)

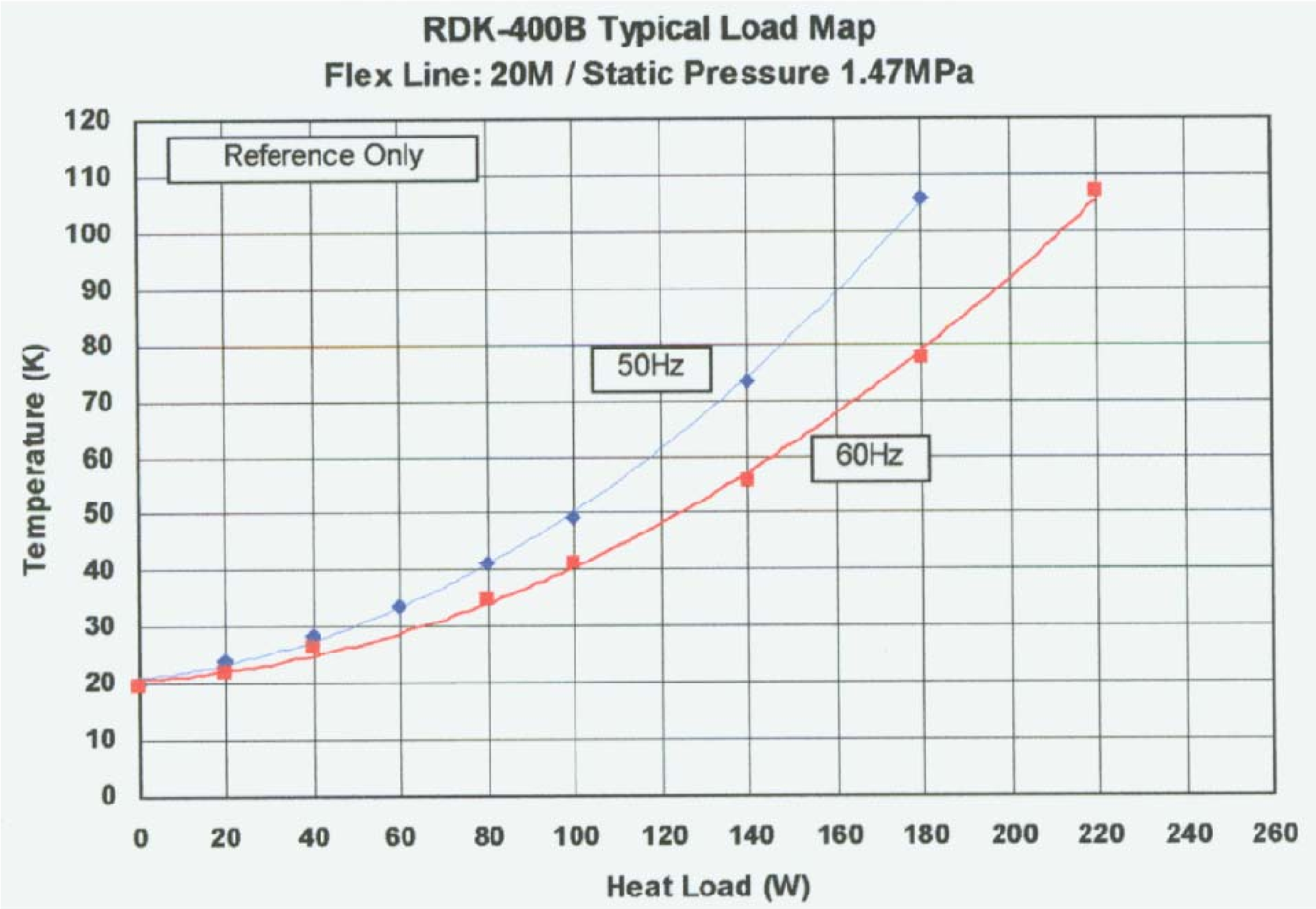
Reuter and Sondheimer, Proceedings of the Royal Society of London, 195:1042, 1948.

Cold Bore Cryostat

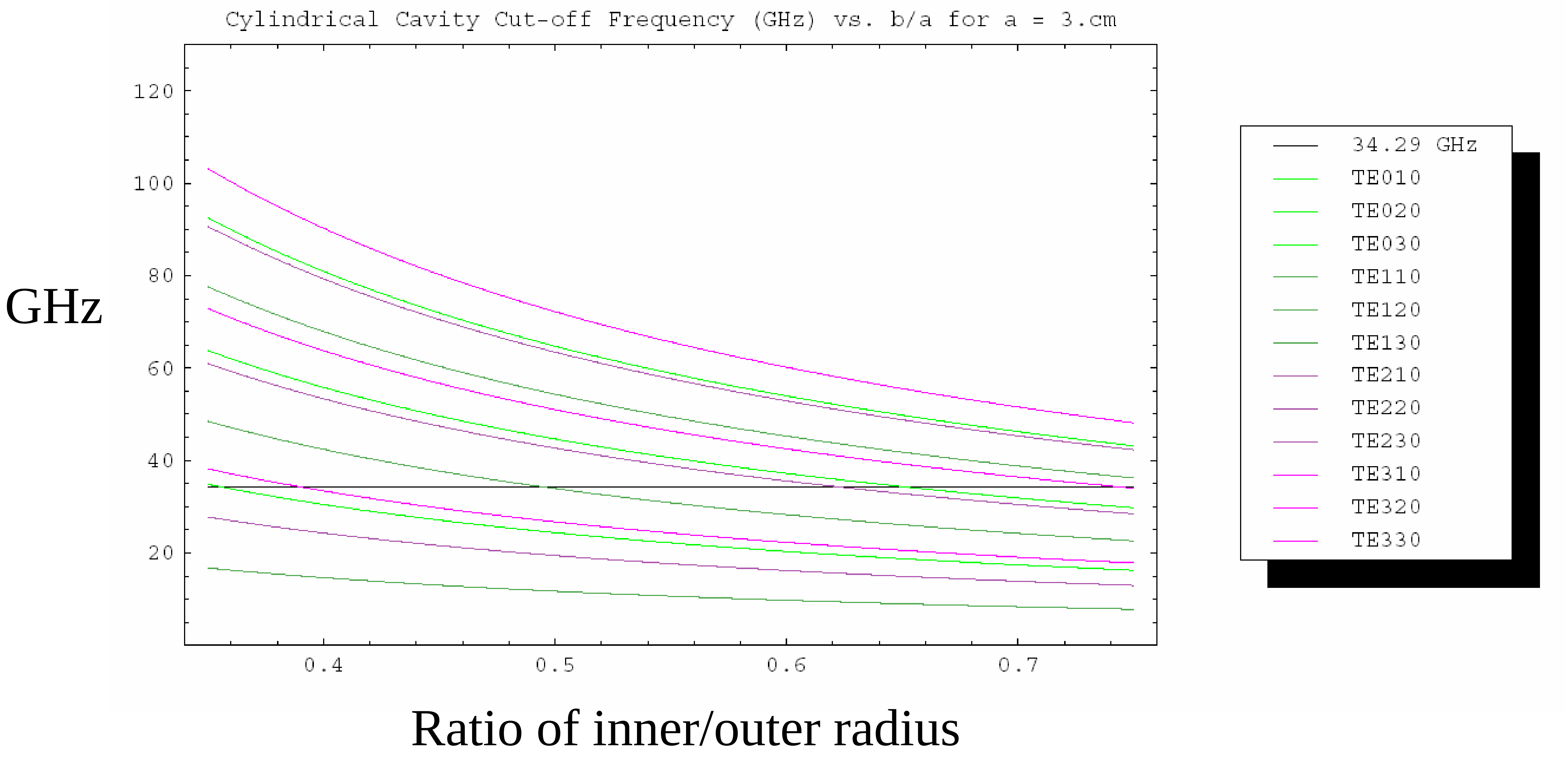


- Vacuum seal at both ends of bore.
- RF waveguides feed through vacuum seal.
- Cryostat can achieve 40K with 100W of heat dissipation.

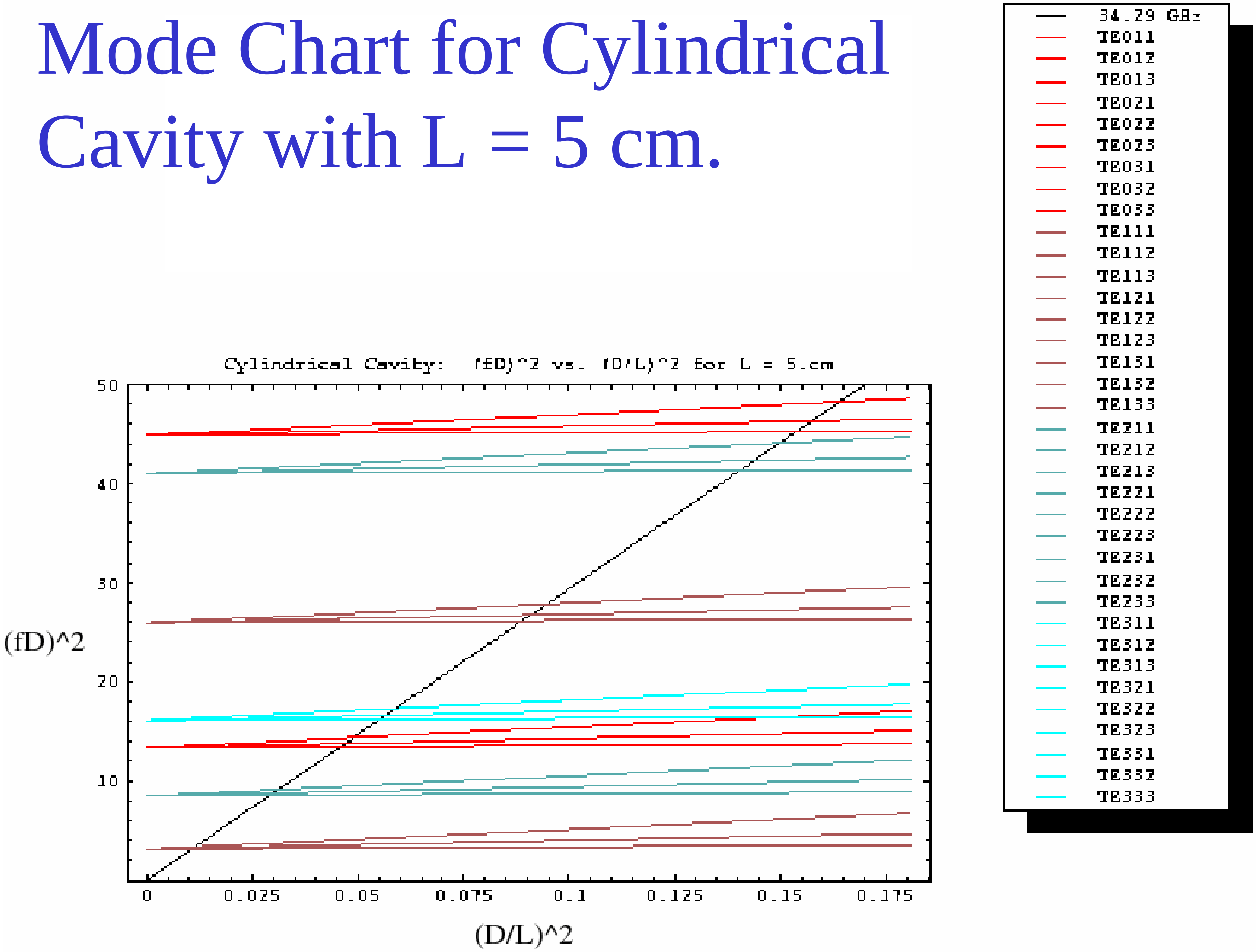
Load Map for Single-Stage Cryocooler



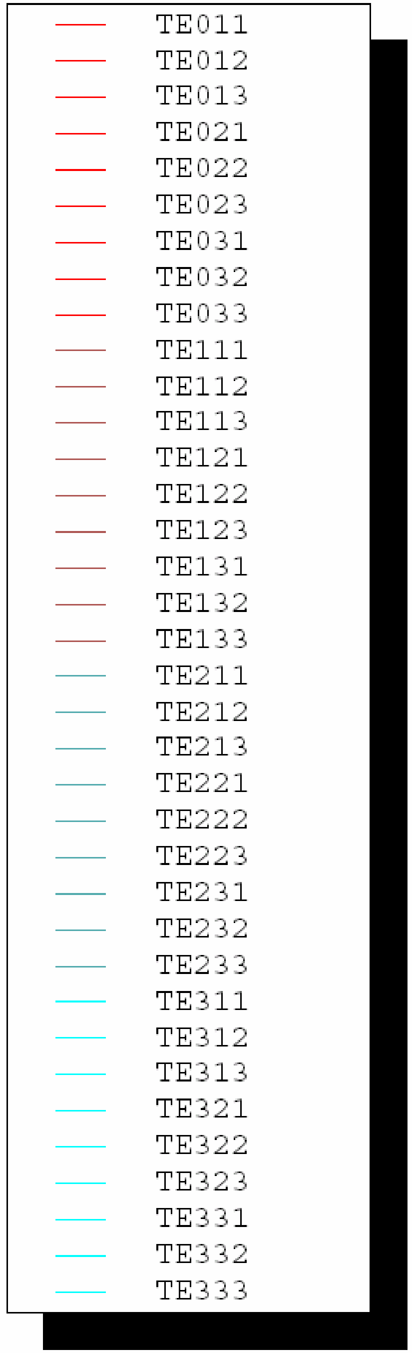
Cut-off Frequencies for Cylindrical Cavity

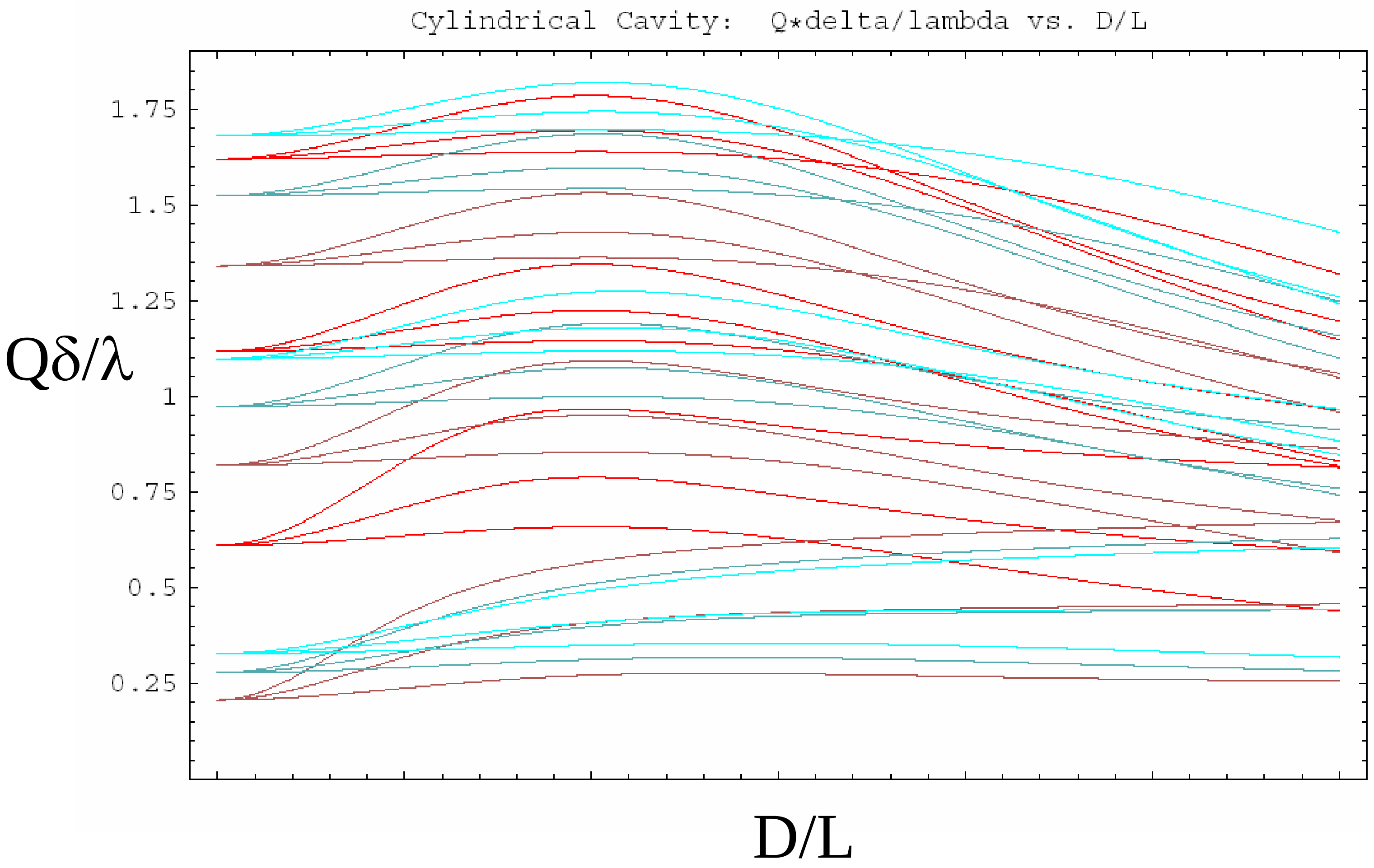


Mode Chart for Cylindrical Cavity with L = 5 cm.

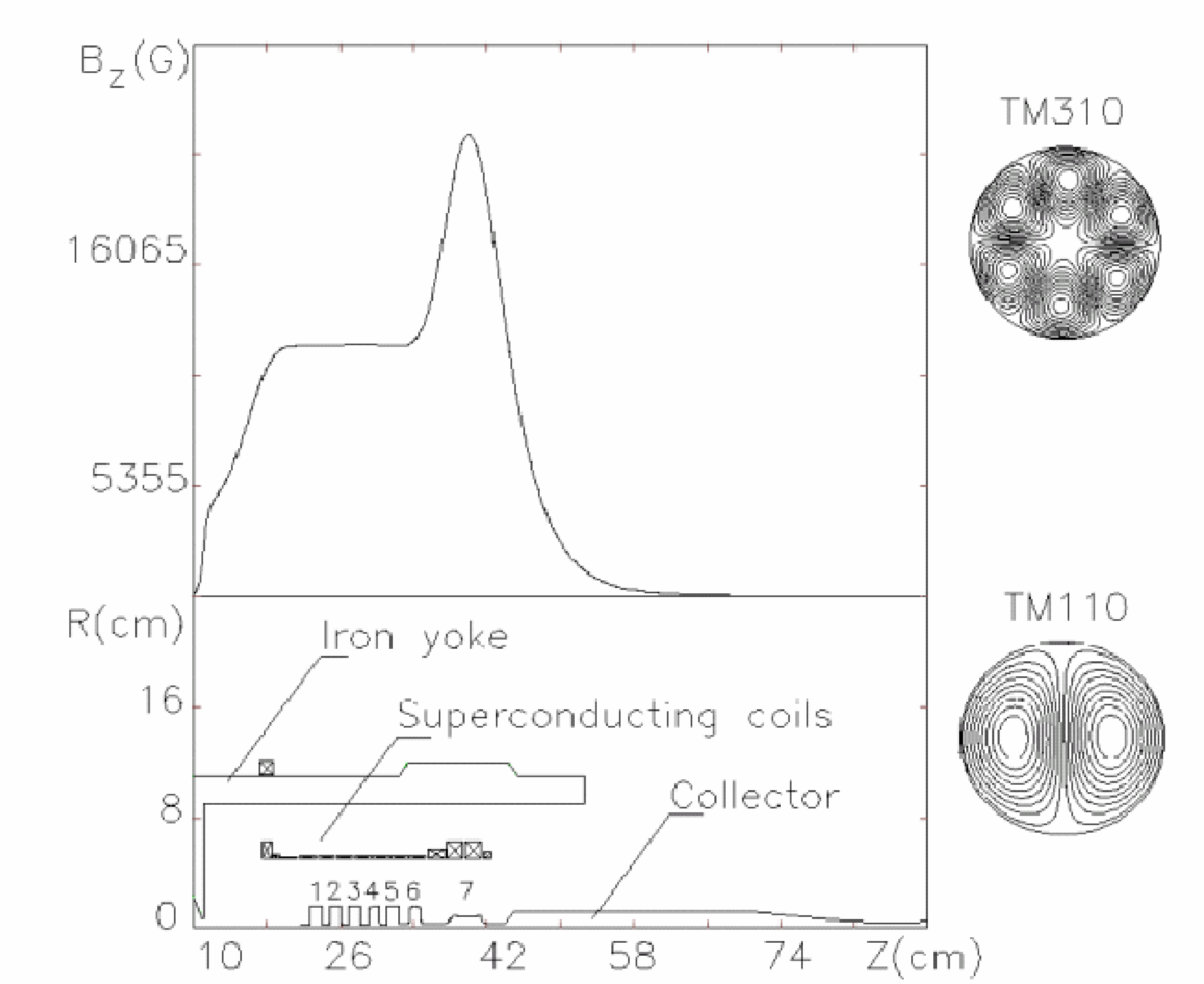


Q Factors for Cylindrical Cavity



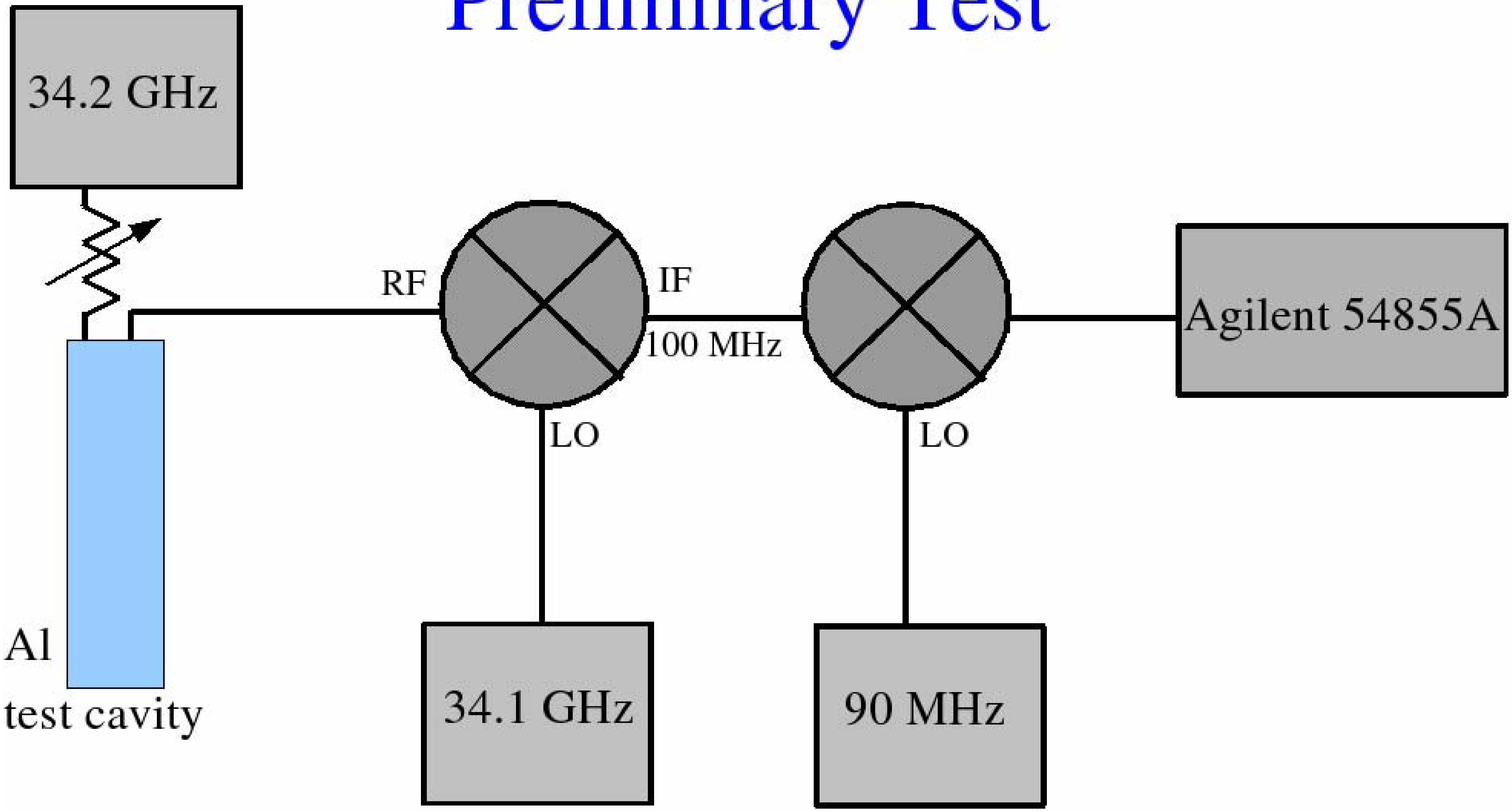


Microwave Source - Axial Layout

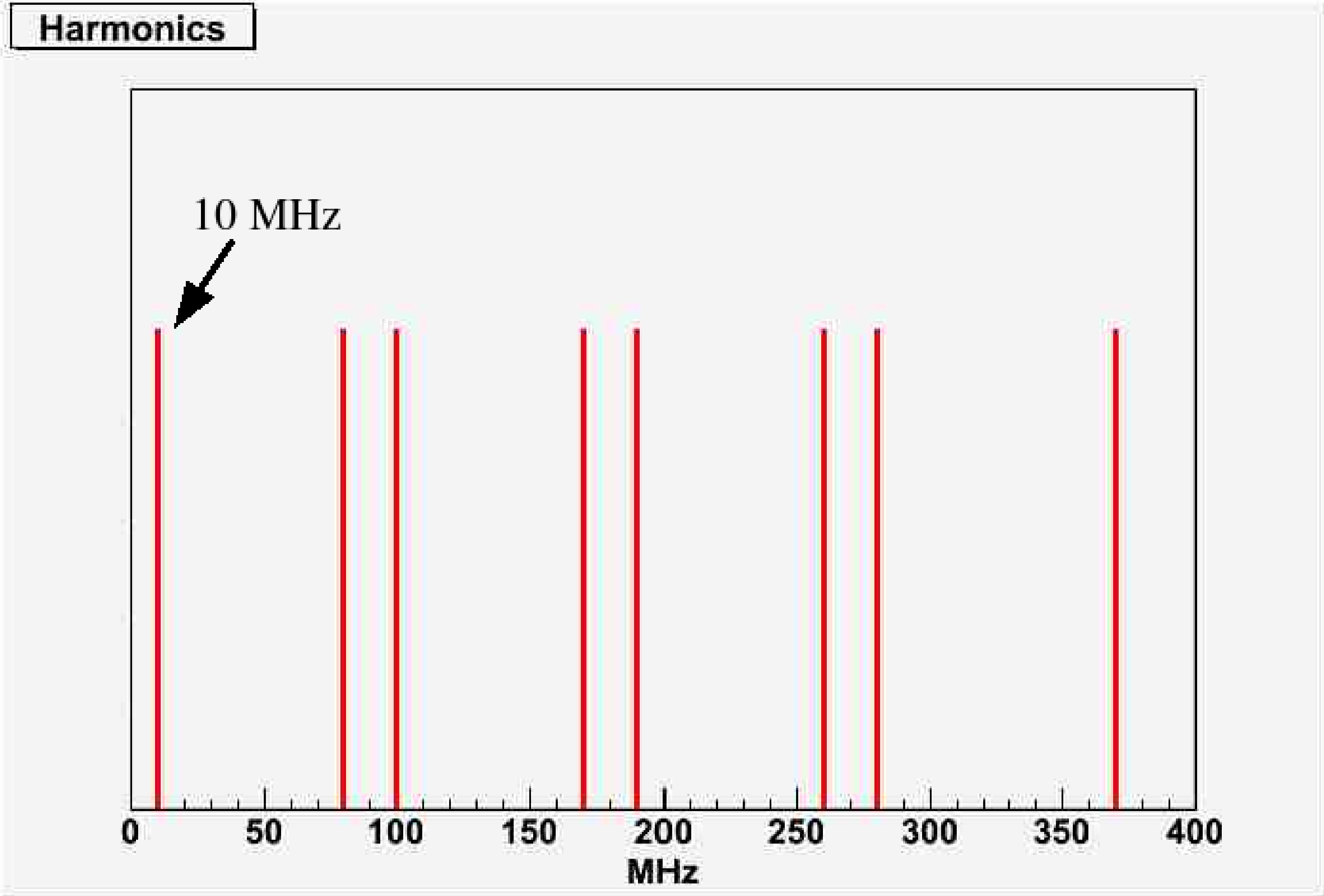


O. A. Nezhevenko et al., Proceedings of EPAC 2004, Lucerne

Preliminary Test



Expected Harmonics



Summary

•High-power 34 GHz microwave source at Yale provides a unique opportunity to search for particles with mass 0.1 meV.

•Design for resonant cavity, magnet, cooling system, and electronics are underway.

•Electronic components have been ordered from Miteq. Delivery expected in July 08 – initial tests with preliminary cavity will begin as soon as equipment arrives.