search for a scalar axion-like particle at 10^{-4} eV

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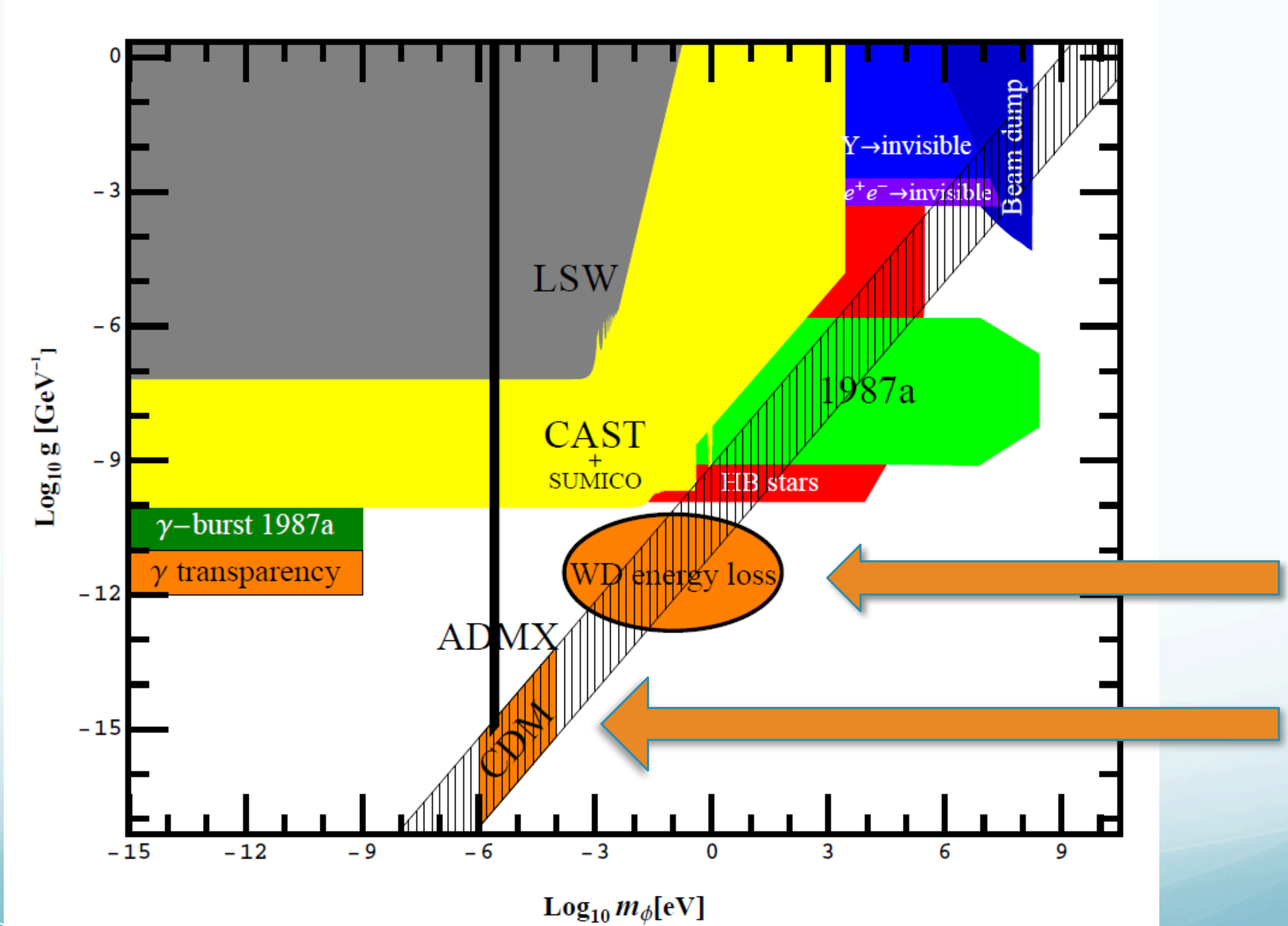
Vistas in Axion Physics 2012

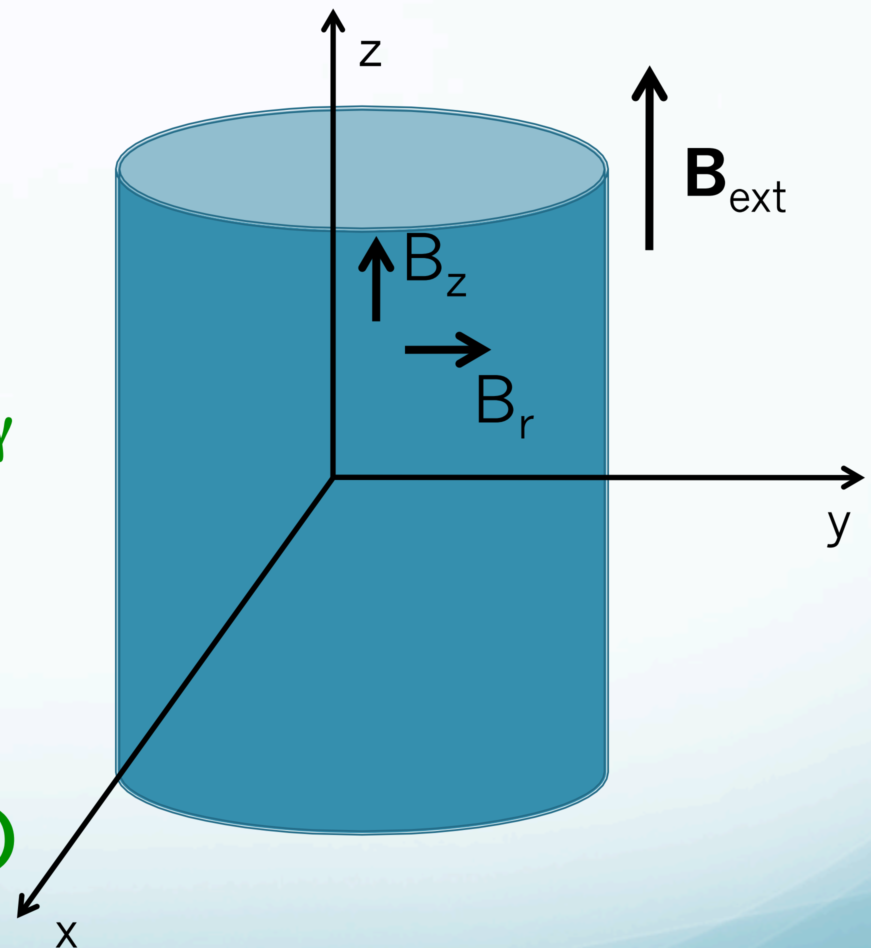
why search near 0.1 meV?



J. Jaeckel and A. Ringwald, Ann. Rev. of Nuc. and Particle Sci., 60, 405, 2010.

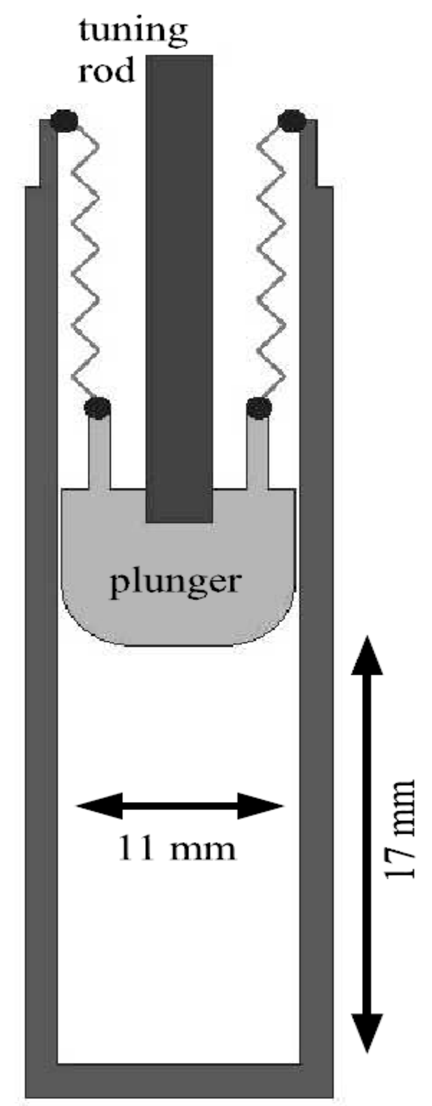
resonant cavity searches

- **pioneered by Pierre Sikivie and ADMX collaborators in 1980s.**
- **ADMX: single low-mode cavity in B-field to look for γγ coupling with local galactic halo axions.**
- **$L = -g\phi B_\gamma \cdot B_{ext}$ (scalar ALP)**
- **$L = -g\phi E_\gamma \cdot B_{ext}$ (pseudoscalar)**

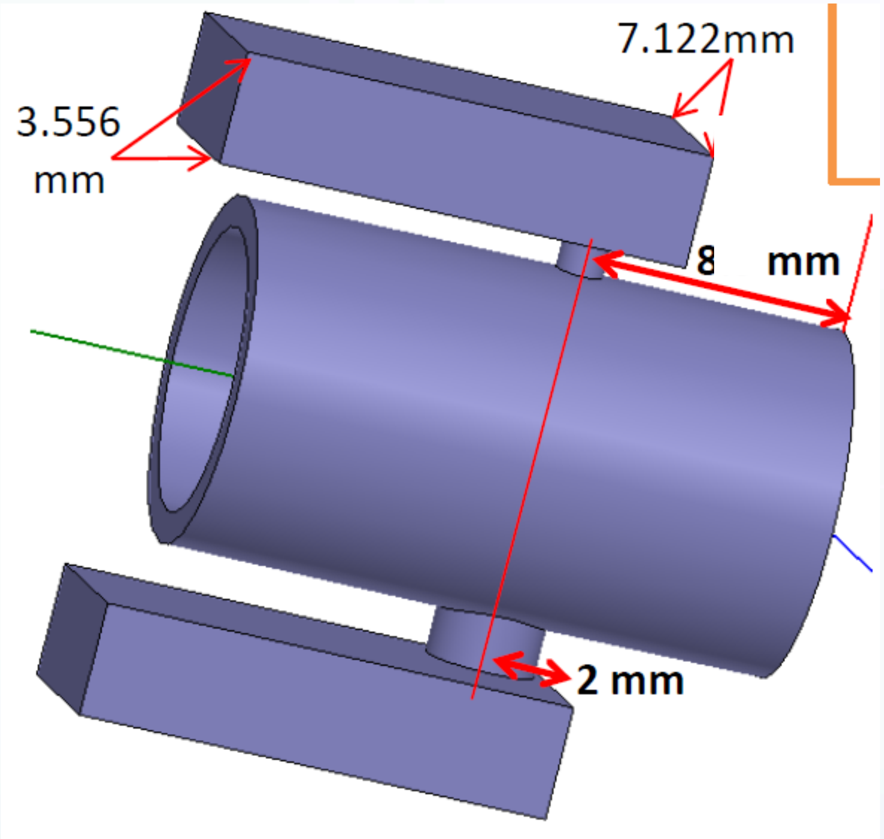


present experiment at 34 GHz

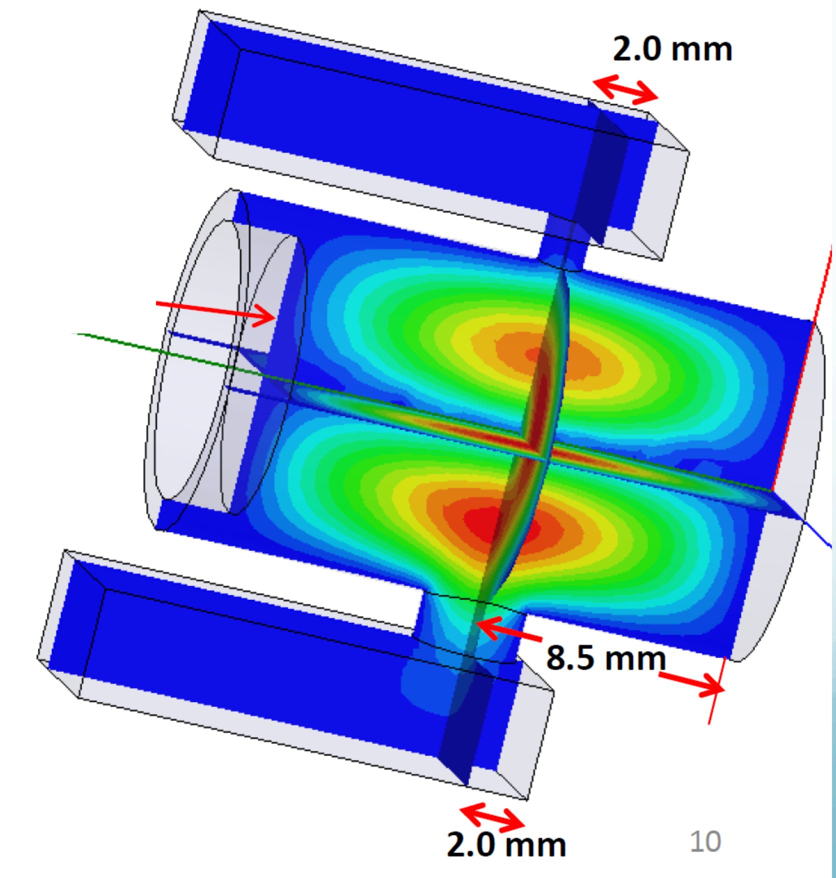
- **Cu resonant cavity at 34 GHz, cooled to T=4 K, tunable, TE_{011} mode.**



cavity field simulation



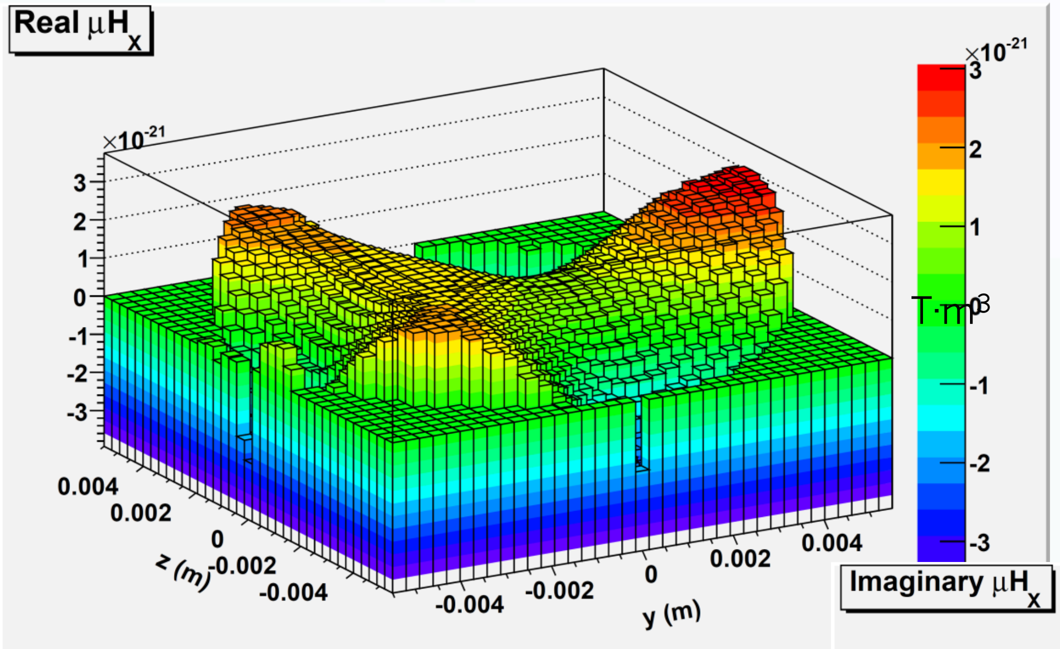
TE_{011} mode:
$E_{\Theta} = J'_0(kr)\sin(\pi z/L)$

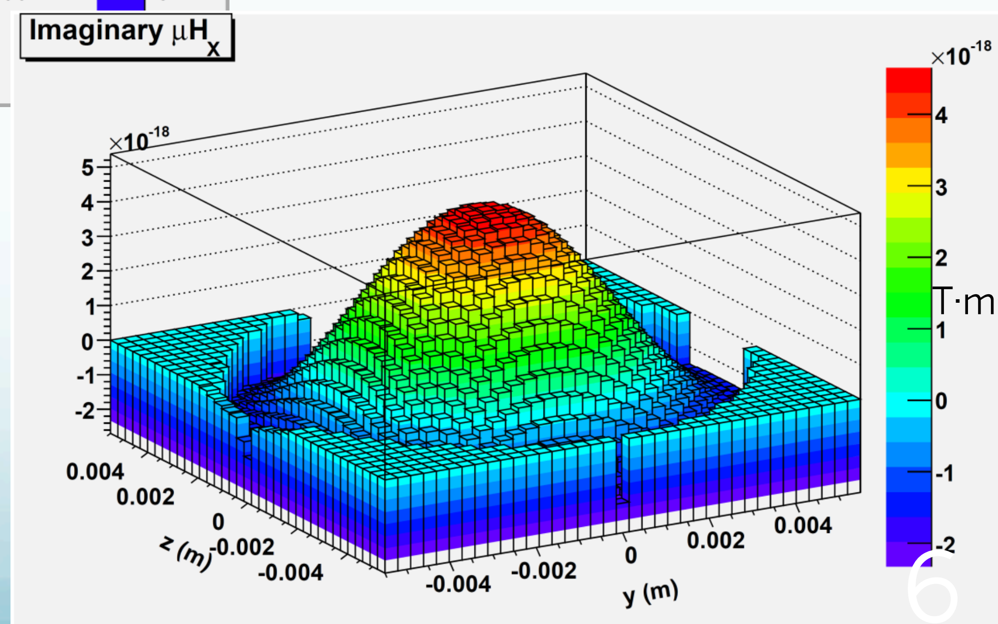


$Q = Q(\lambda/\delta)$, $\delta = (2\rho/\omega\mu)^{1/2}$,

→ Q increases with cooling.

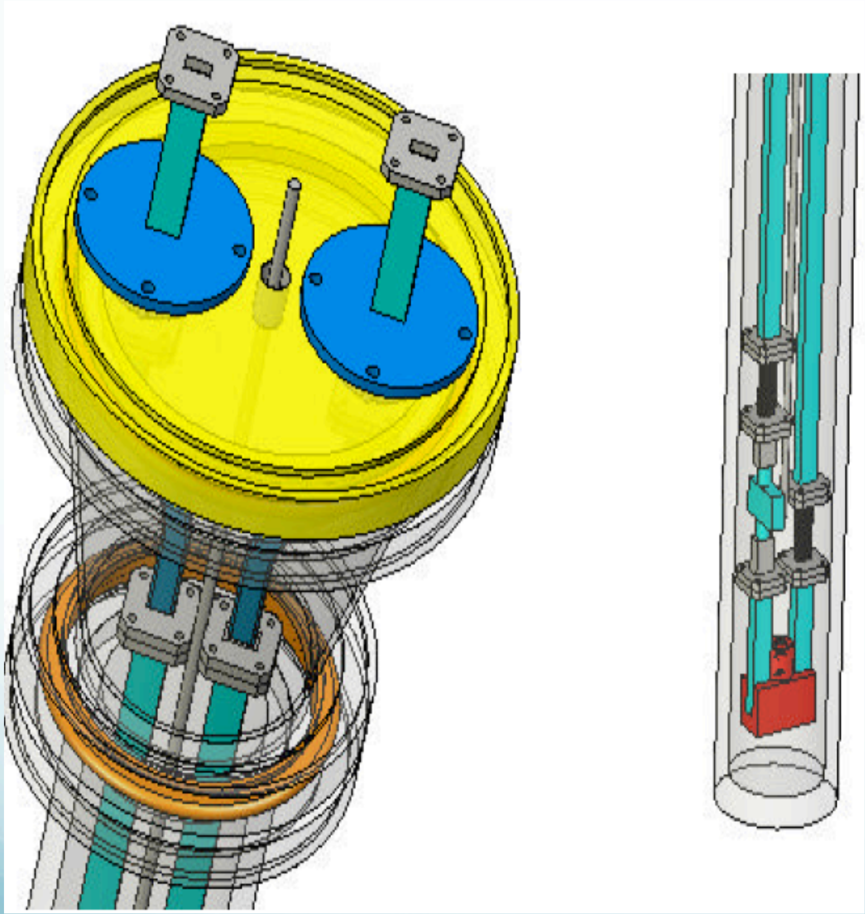
simulated axial B fields



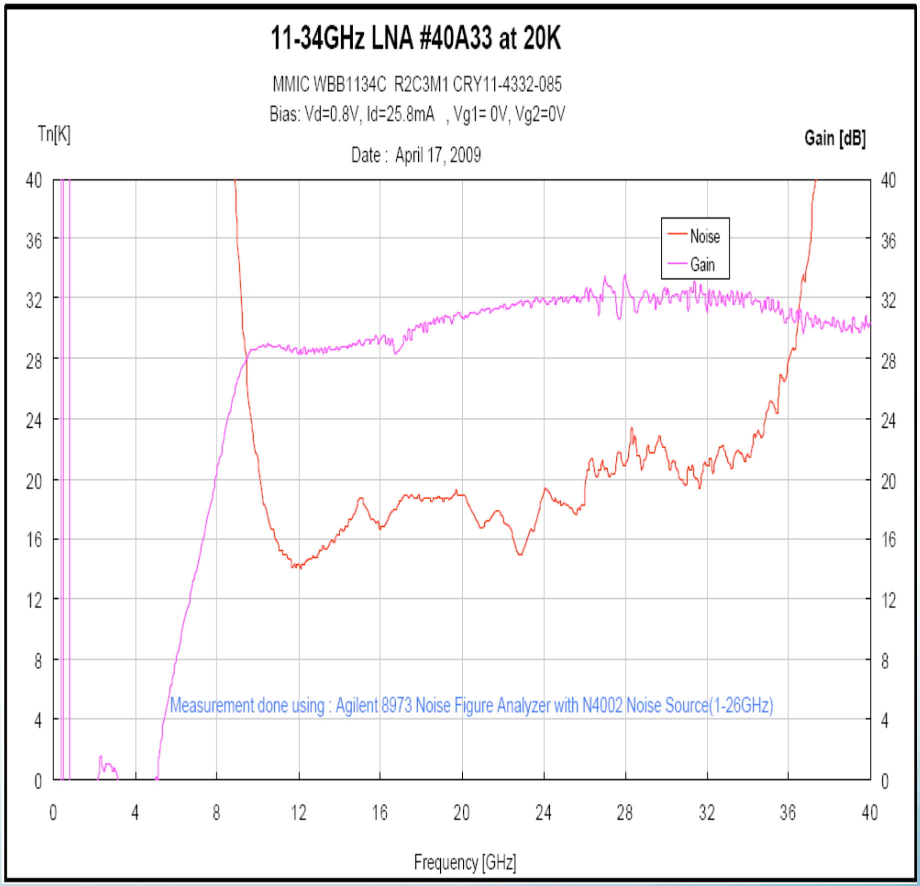


$C_{lmn} \sim O(10^{-6})$

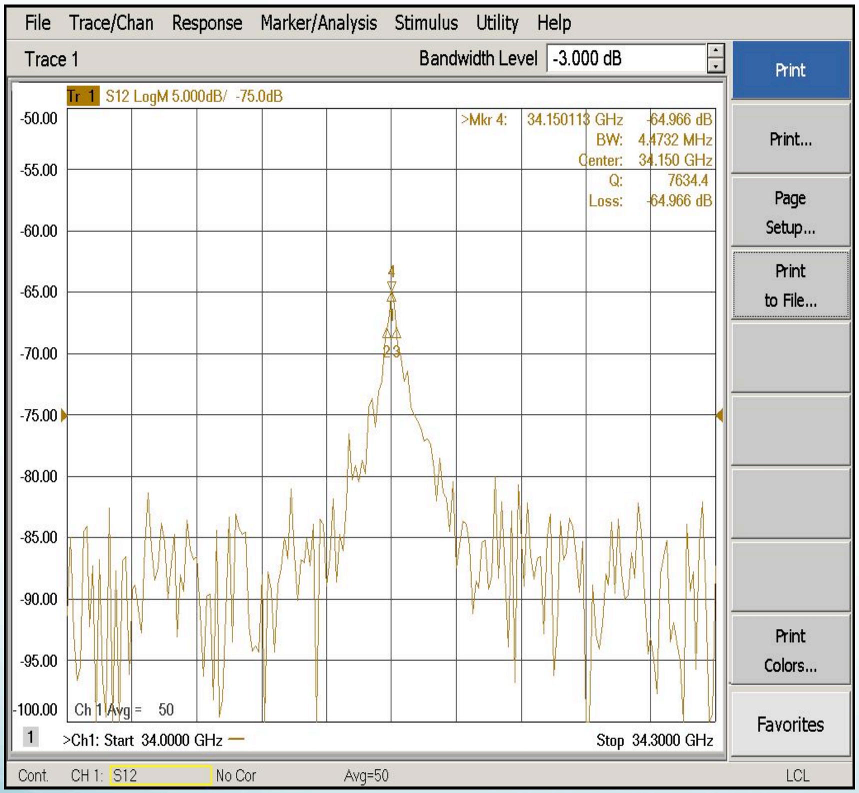
WR-28 waveguide input/output



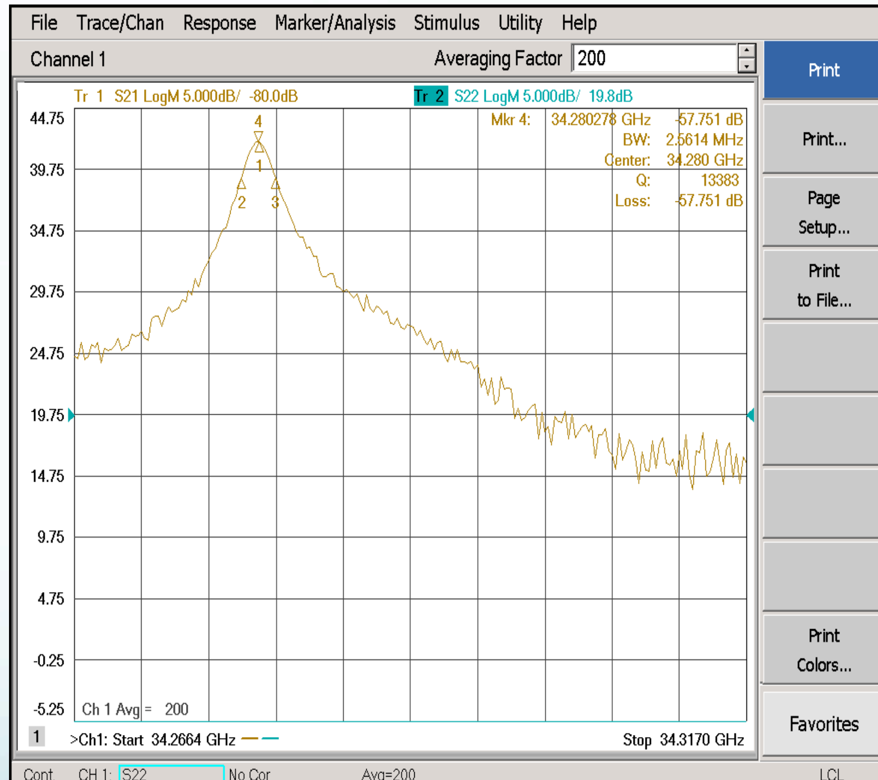
cryogenic HEMT amplifier



cavity resonance at room temperature Q=7500

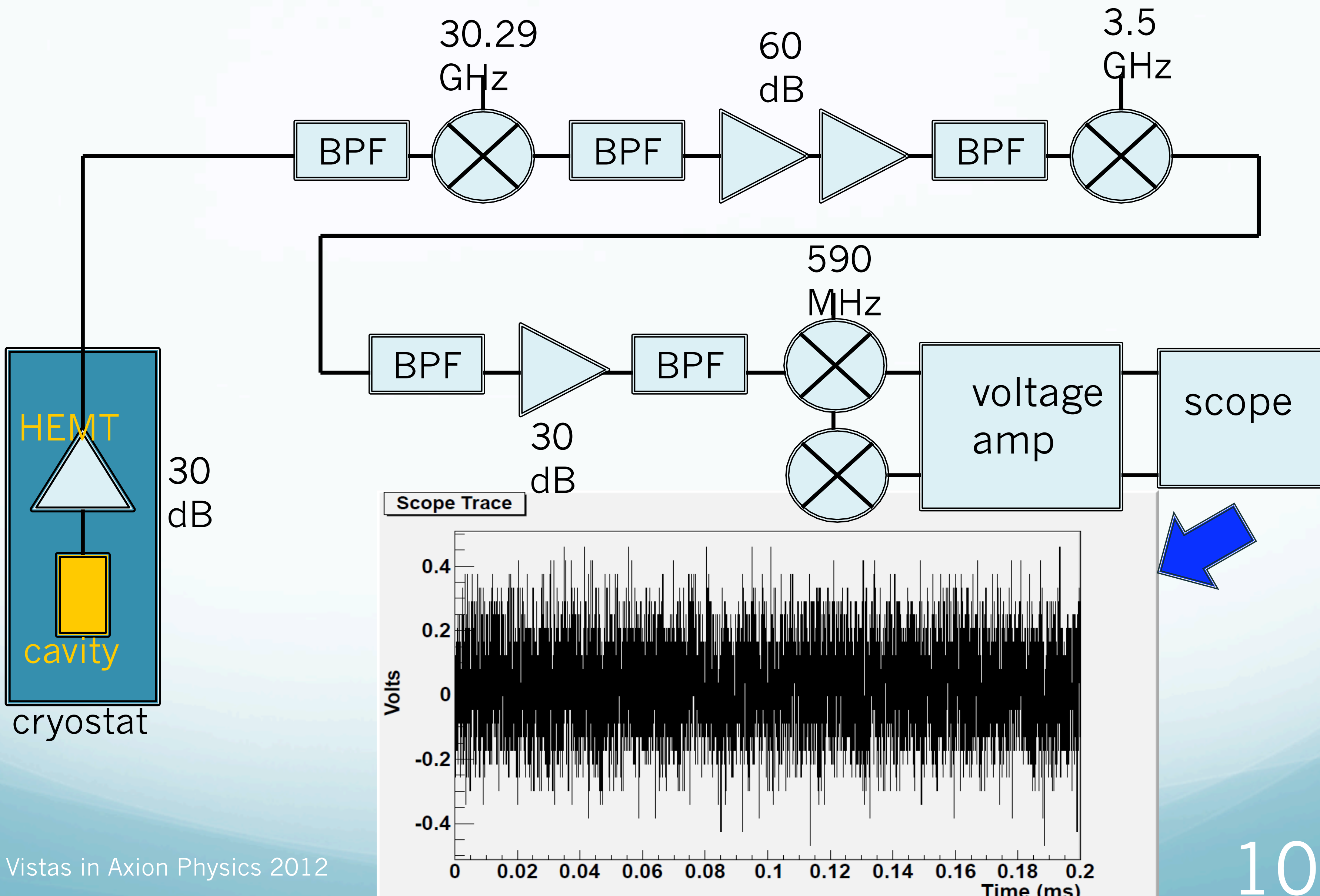


cavity resonance at T = 6 K Q=13383

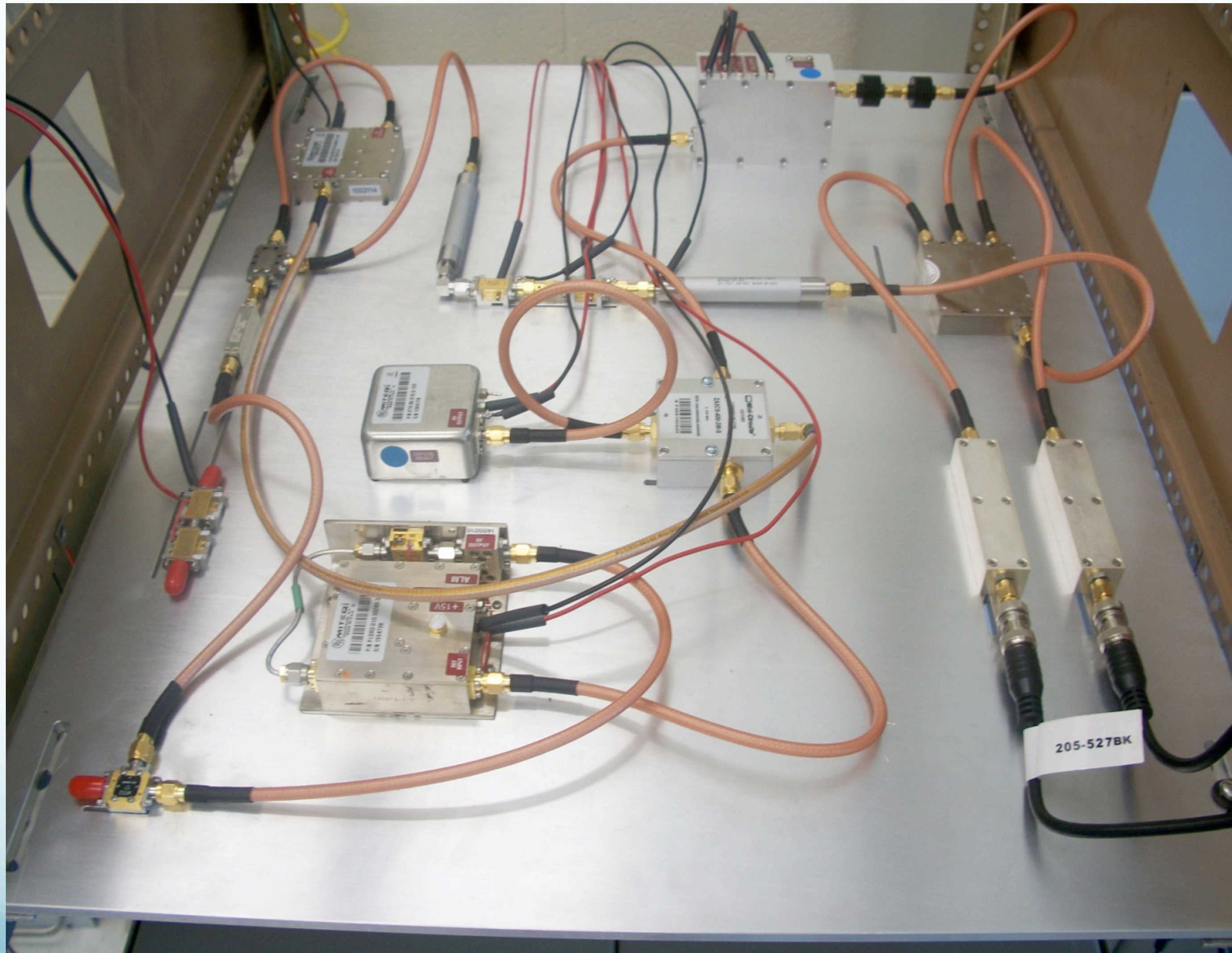


experimental layout

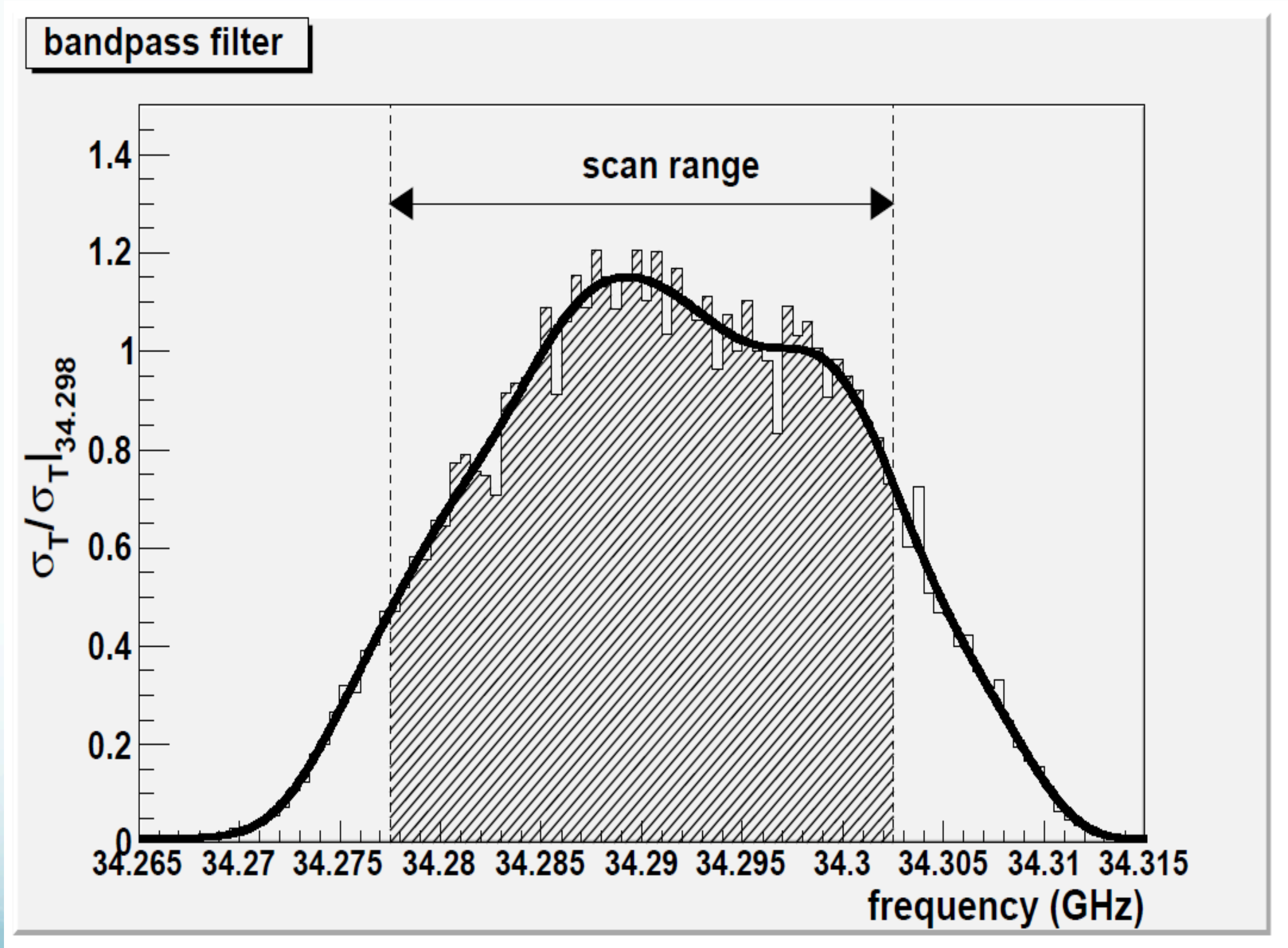
microwave receiver



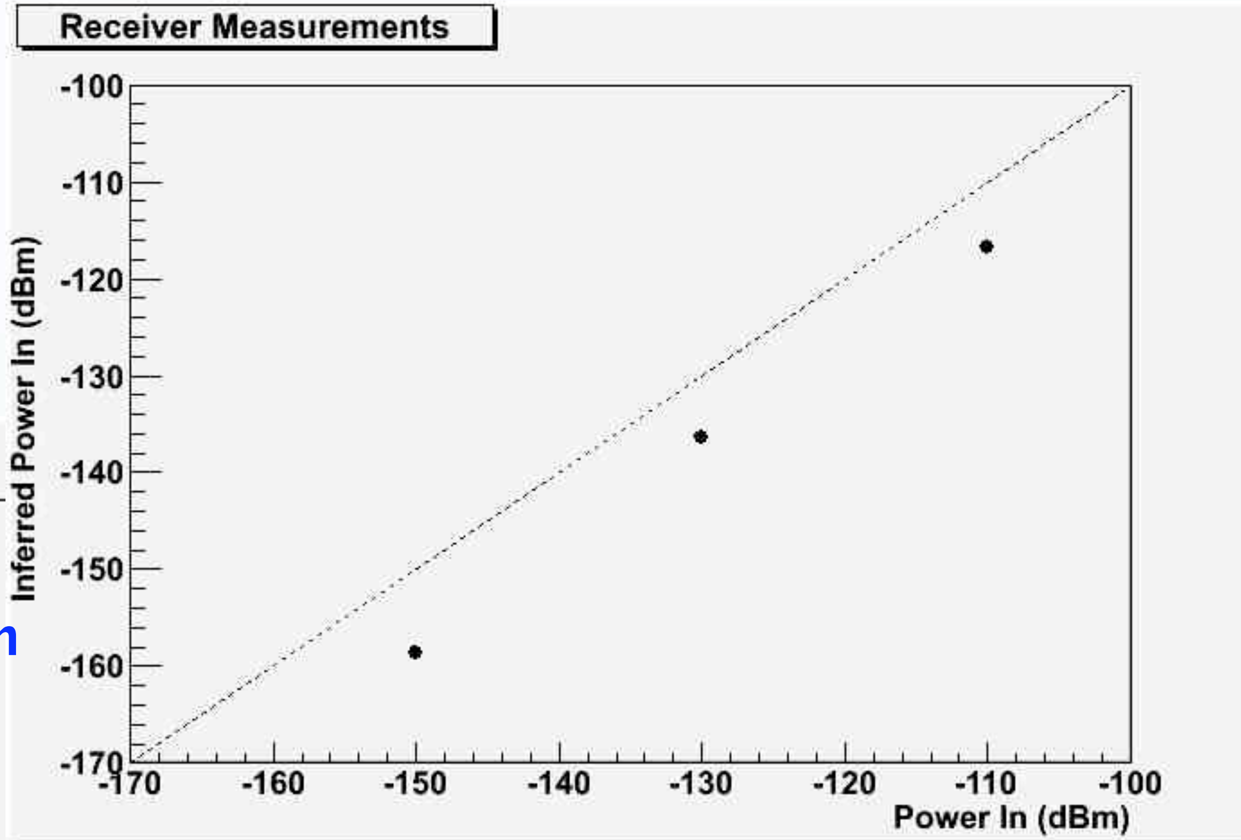
receiver layout

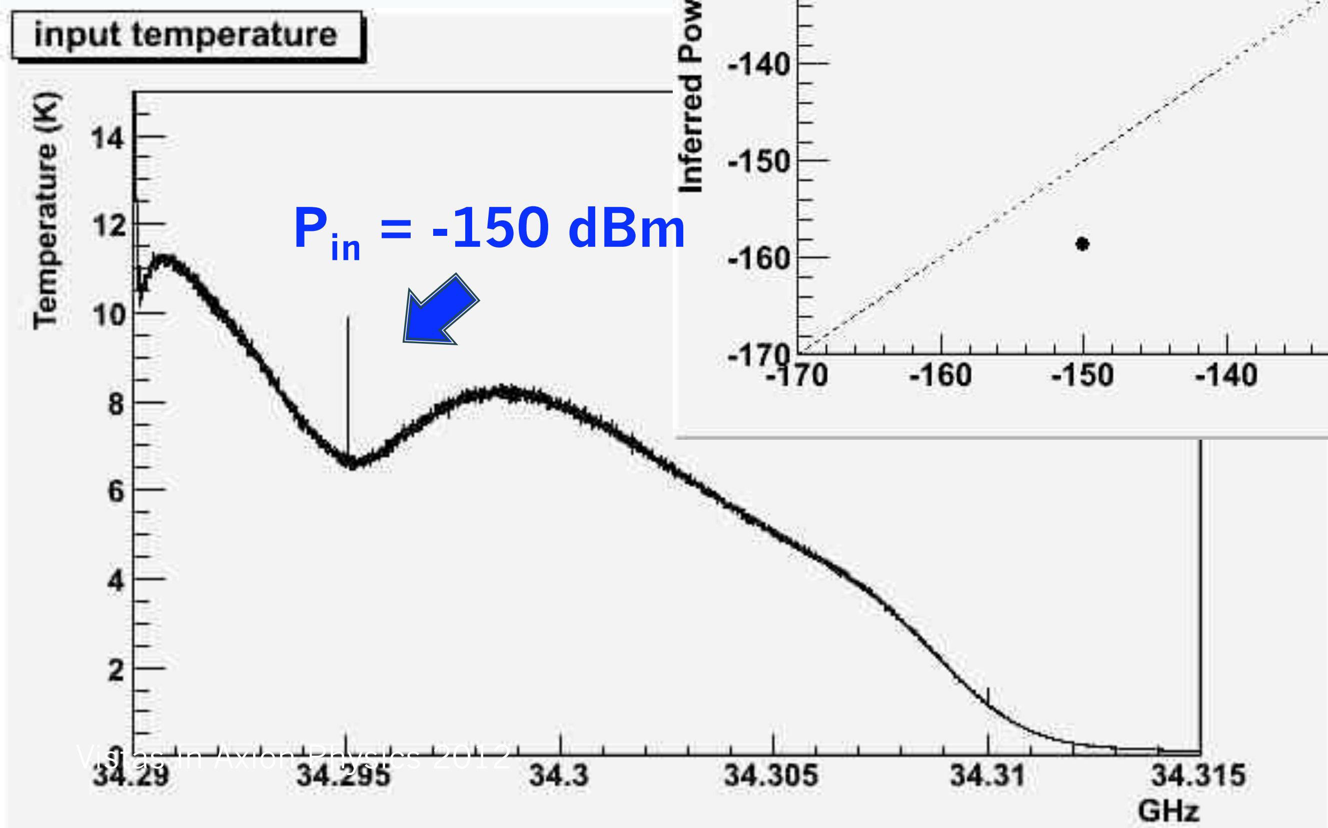


receiver passband



receiver tests





sensitivity

Dicke radiometer equation:

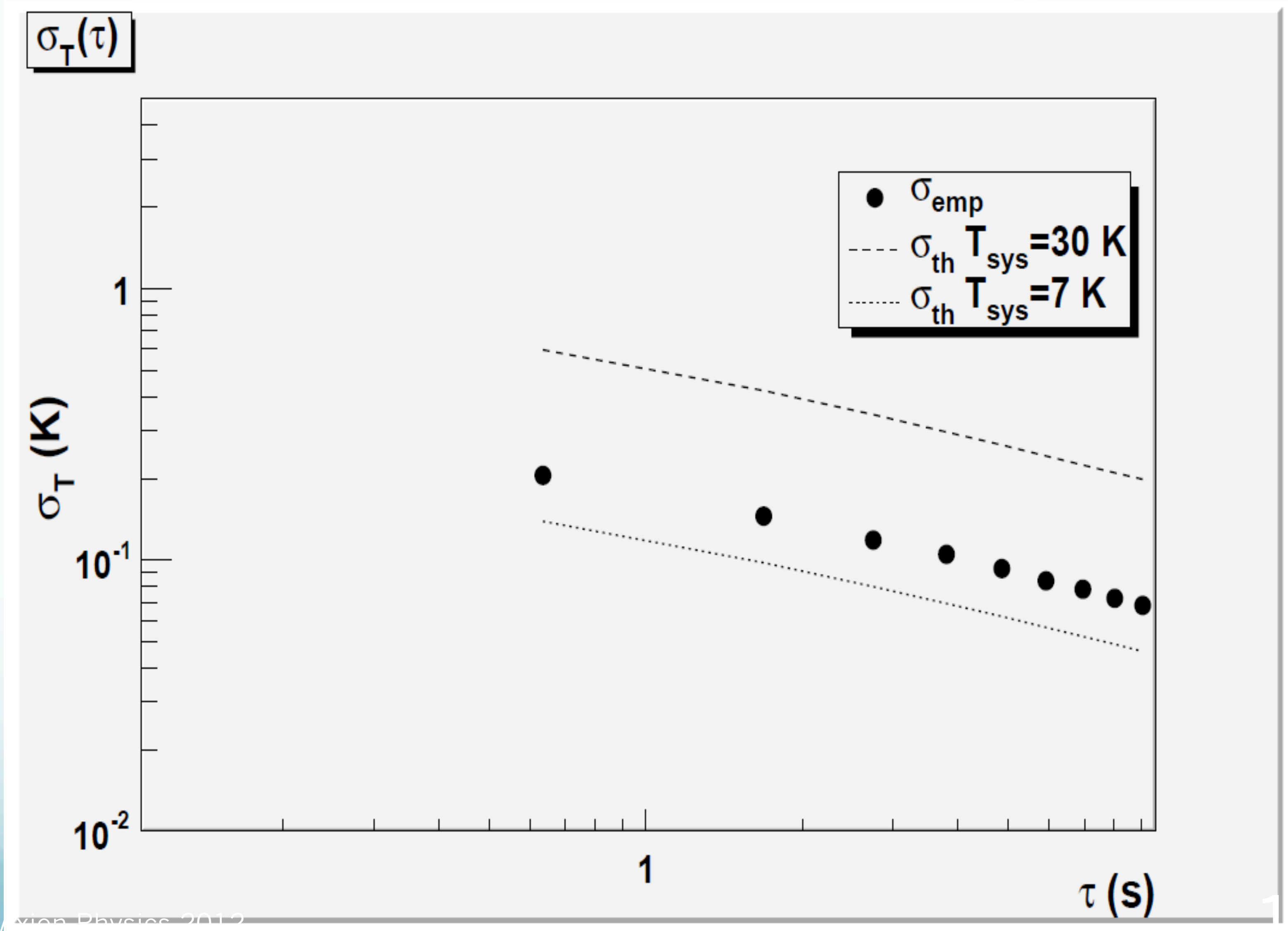
$$5\sigma_T = 5\frac{T_{sys}}{\sqrt{\Delta\nu_{RF}\tau}}.$$

$T_{sys} = T_{cavity} + T_{hemt} = 32$ K

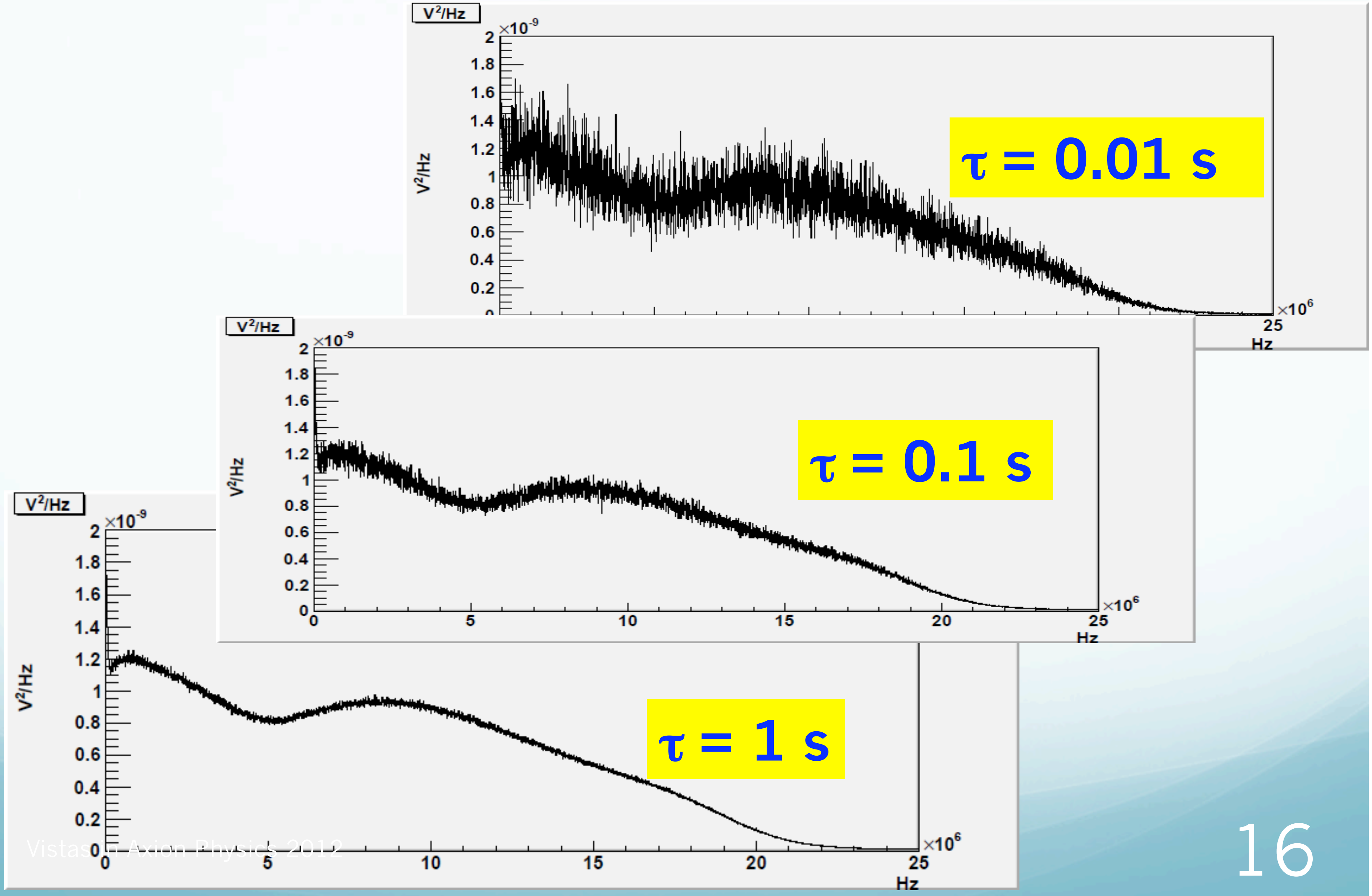
$\Delta\nu_{RF} = 1$ MHz, $\tau = 1$ s

→ $P_{min} = 2 \times 10^{-18}$ W

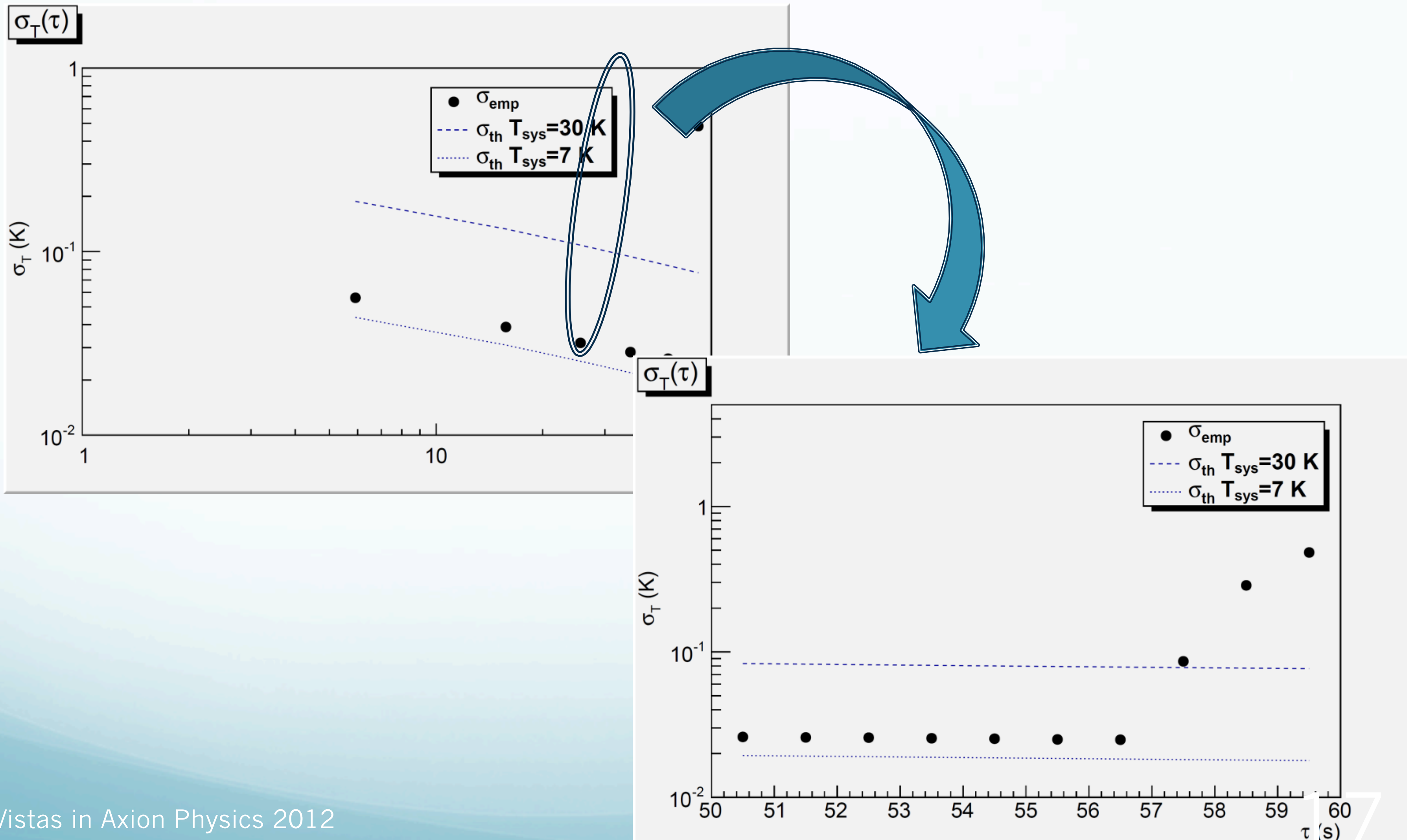
system noise temperature



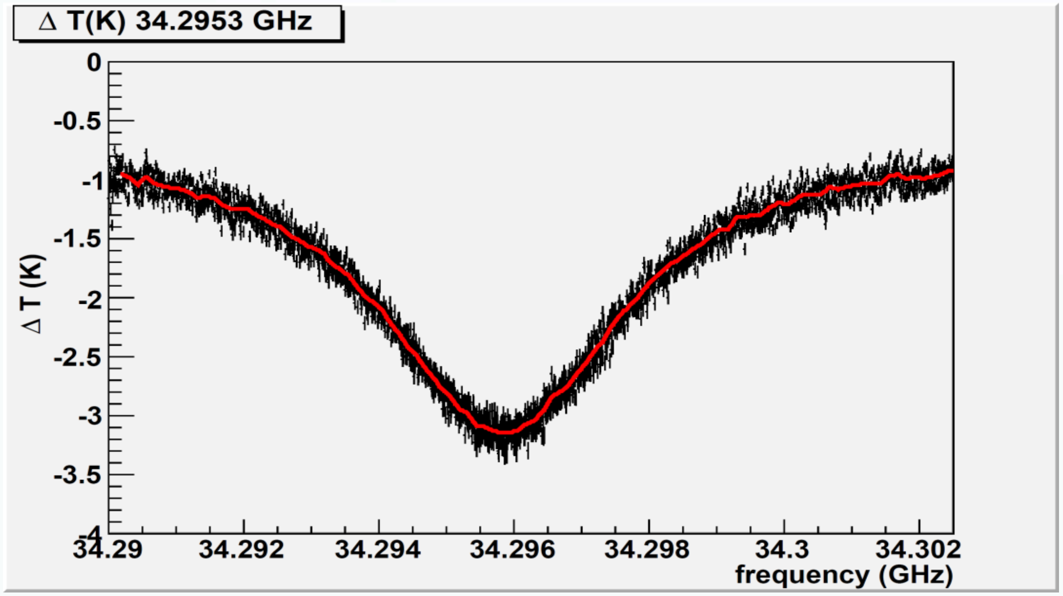
power at oscilloscope



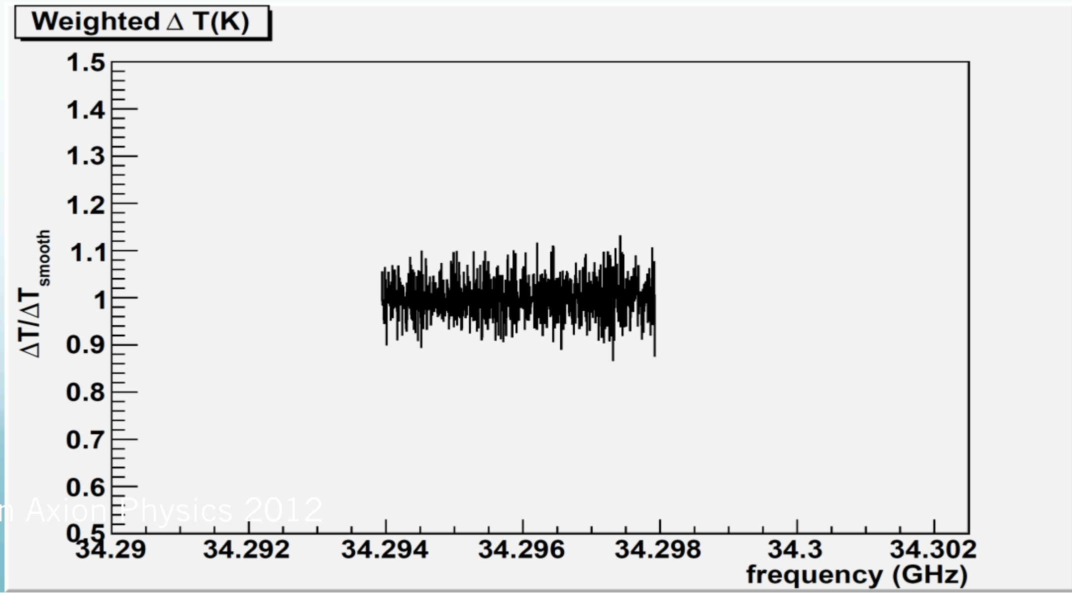
integration time = 1 minute



one scan, cavity tuned to 34.295 GHz

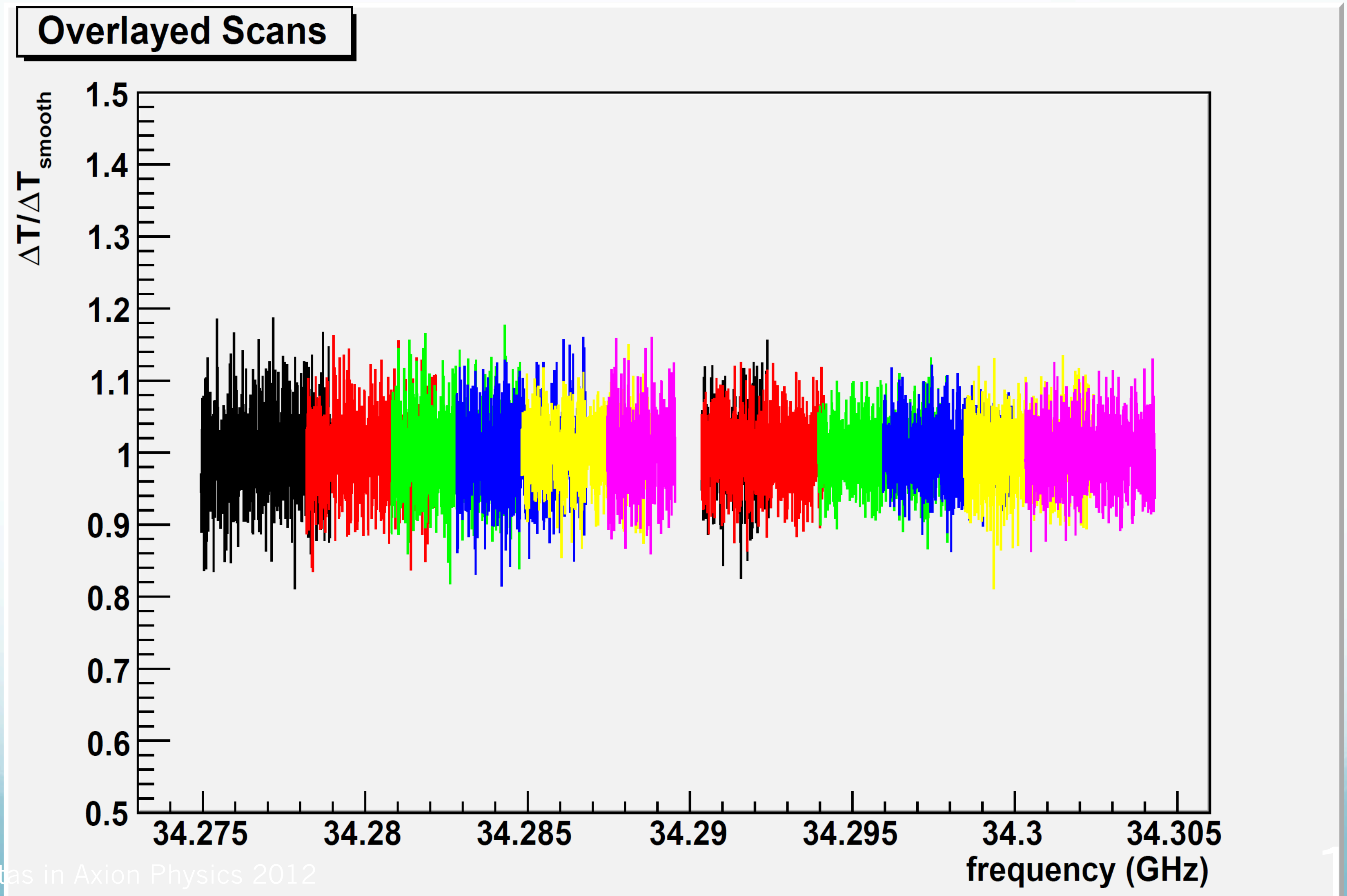


after baseline subtraction

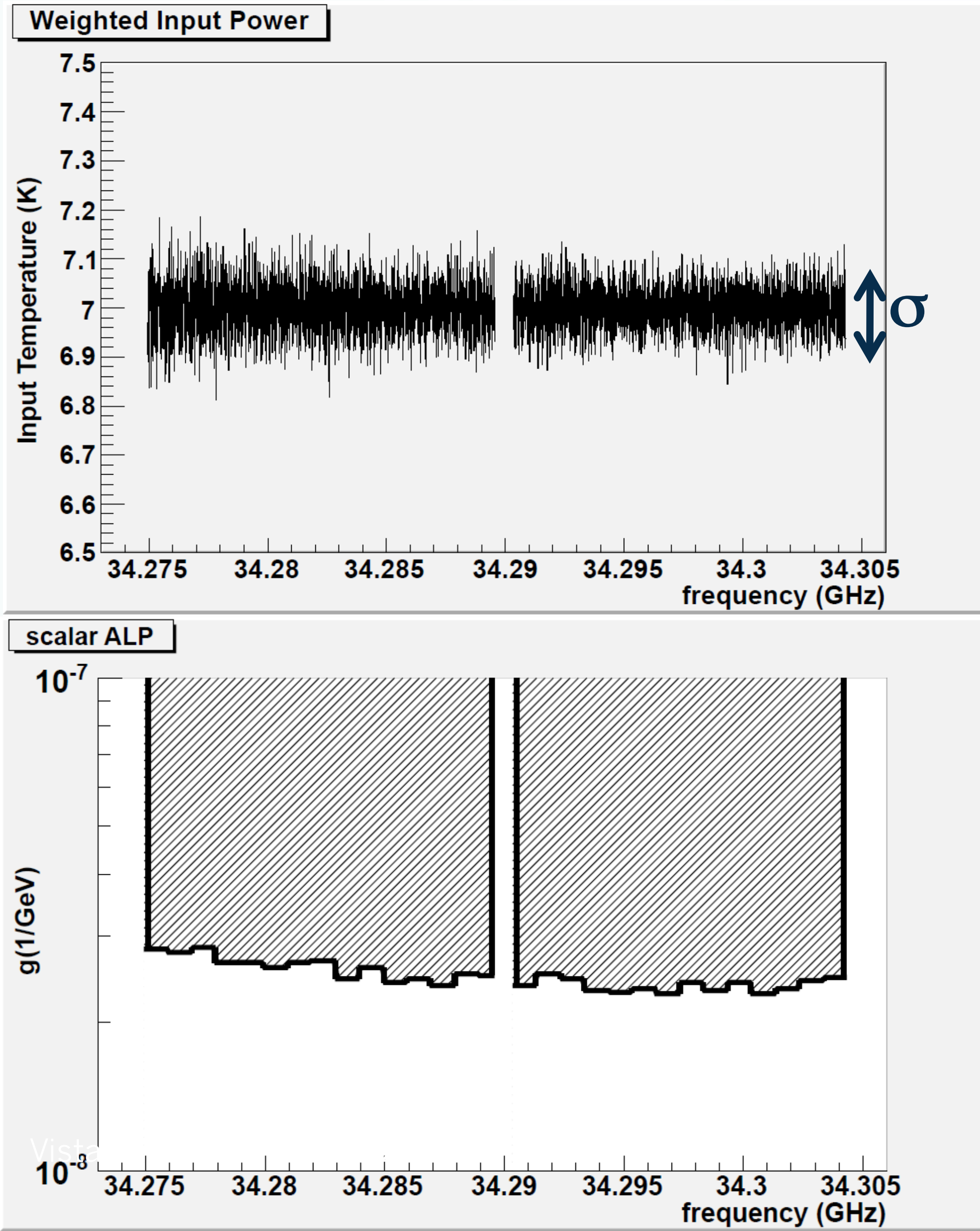


after baseline subtraction and weighting, cut on cavity

overlayed scans



averaged scans and results

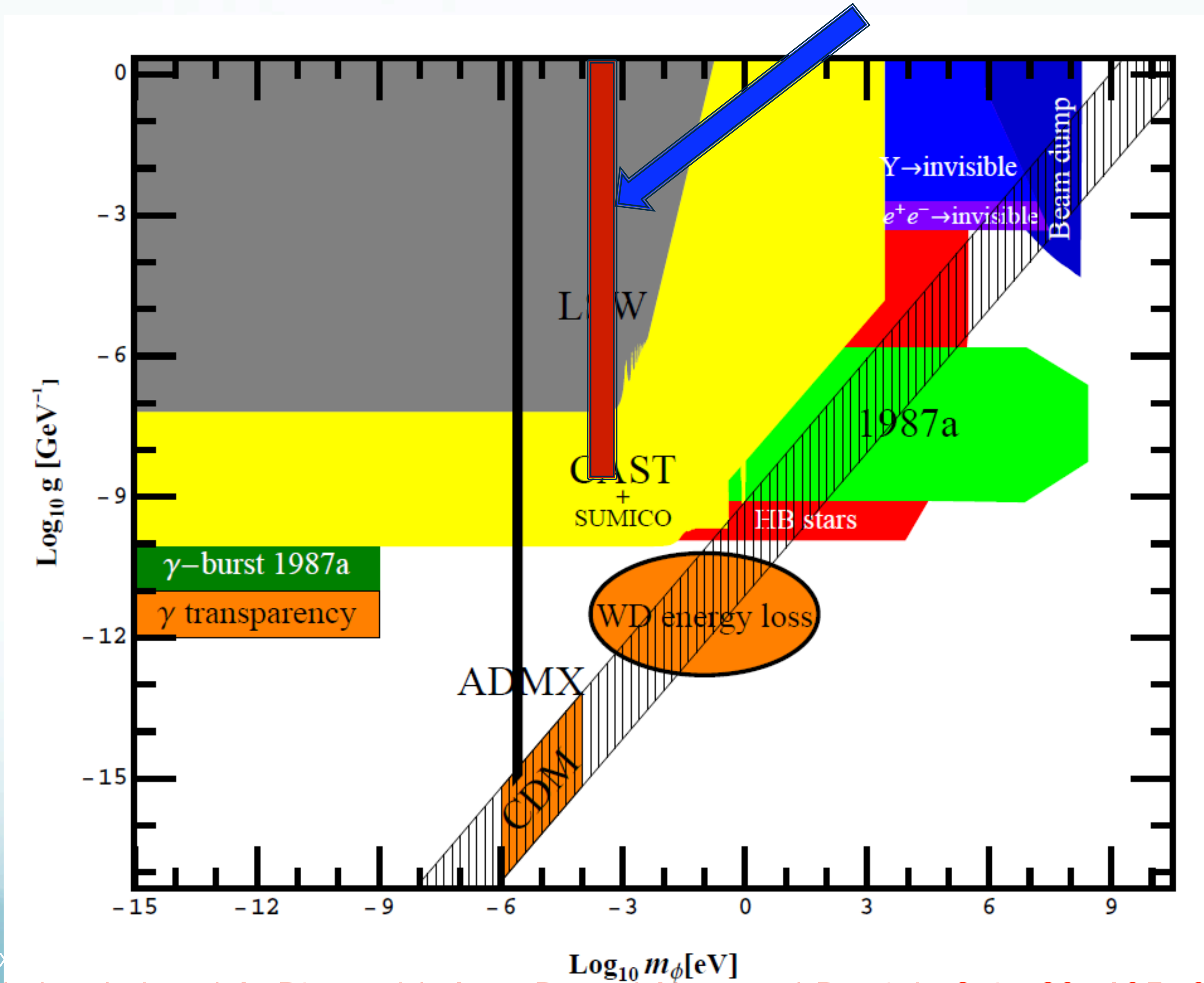


$$P_{S\gamma} = g^2_{S\gamma\gamma} V B^2_{ext} \rho_a C_{lmn} Q$$

$$C_{lmn} \equiv \frac{\left| \int_V d^3x \mathbf{B} \cdot \hat{\mathbf{B}}_{\rm ext} \right|^2}{V \int_V d^3x \frac{1}{\mu} \left|\mathbf{B}\right|^2}$$

submitted for publication

status of axions and ALPs



J. Jaeckel and A. Ringwald, Ann. Rev. of Nuc. and Particle Sci., 60, 405, 2010.

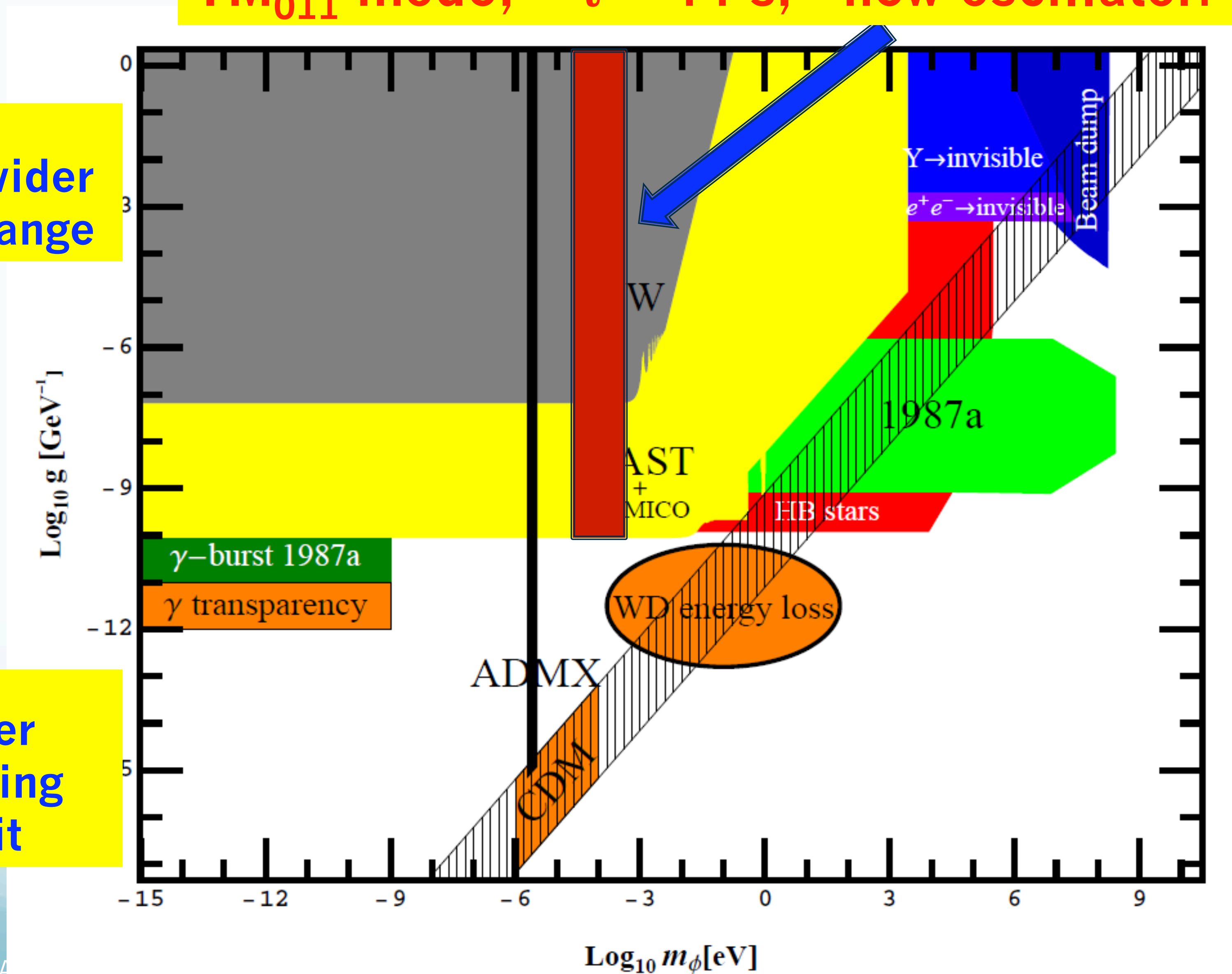
near term plans

- **increase mass region (new osc; wider tuning range)**
- **increase integration time**
- **pseudoscalar (0^- particle) halo axion search**
- **hidden sector paraphoton (1^-) search**
- **chameleon search**

TM_{011} mode; τ = 44 s, new oscillator.

cover wider mass range

larger coupling limit

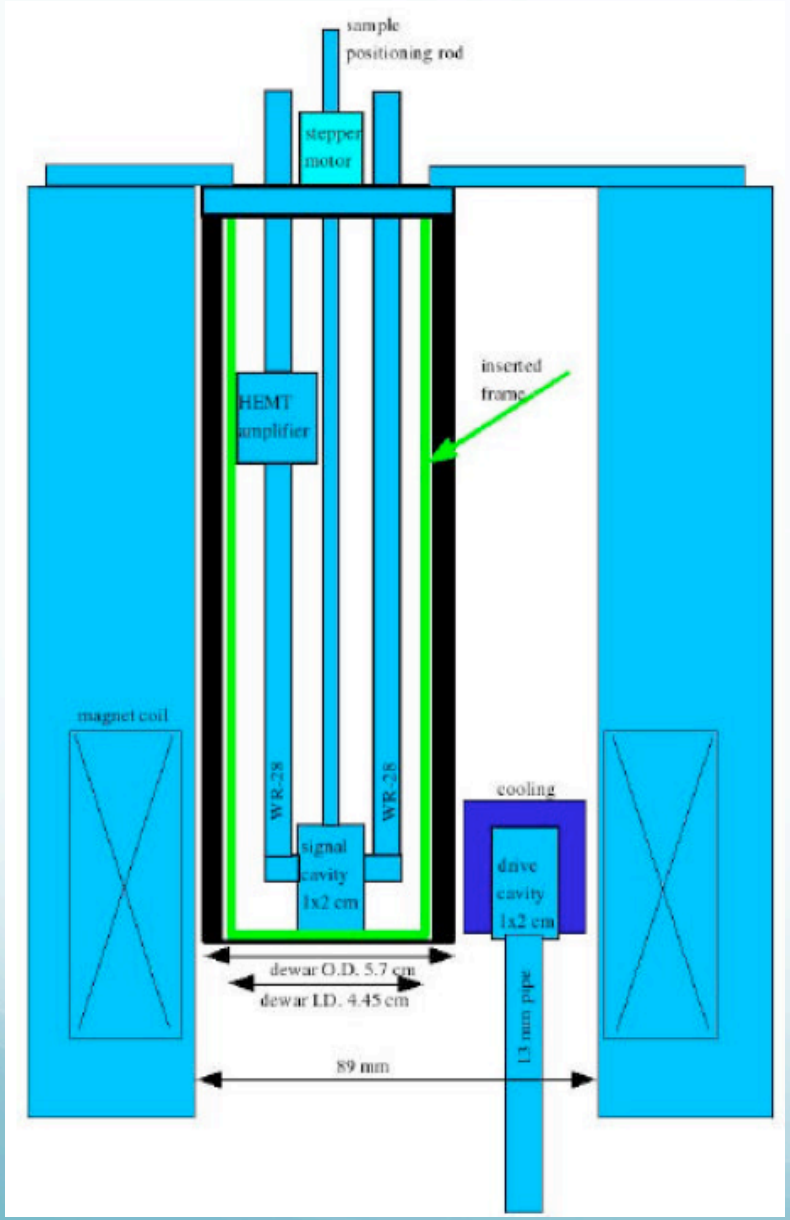


J. Jaeckel and A. Ringwald, Ann. Rev. of Nuc. and Particle Sci., 60, 405, 2010.

summary

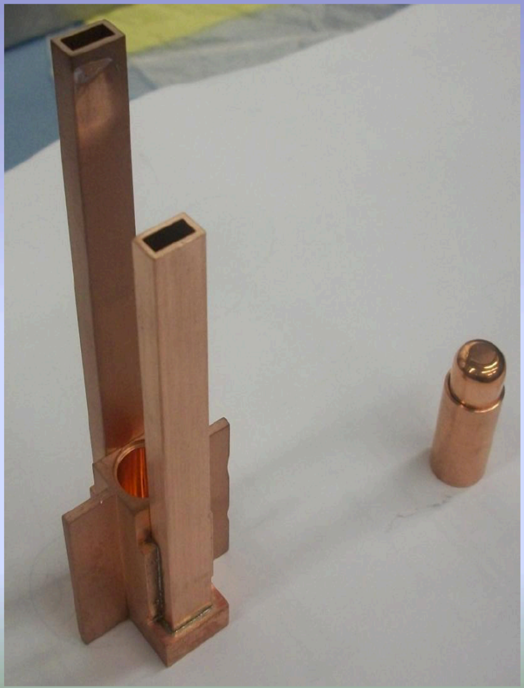
- first resonant cavity search for 10^{-4} eV scalar ALPs
  - resonant cavity at 34 GHz
  - favored by ALP CDM and WD star anomalous cooling rate
- continued improvements in apparatus and procedures
  - wider tuning range
  - more stable running
- plans for near-term future
  - hidden sector photon, chameleon searches
  - pseudoscalar search (TM_{010} mode)

additional slides



- **drive cavity (100 watts avg power)**
- **7 T magnetic field**
- **1 cm x 1 cm Cu cavities**

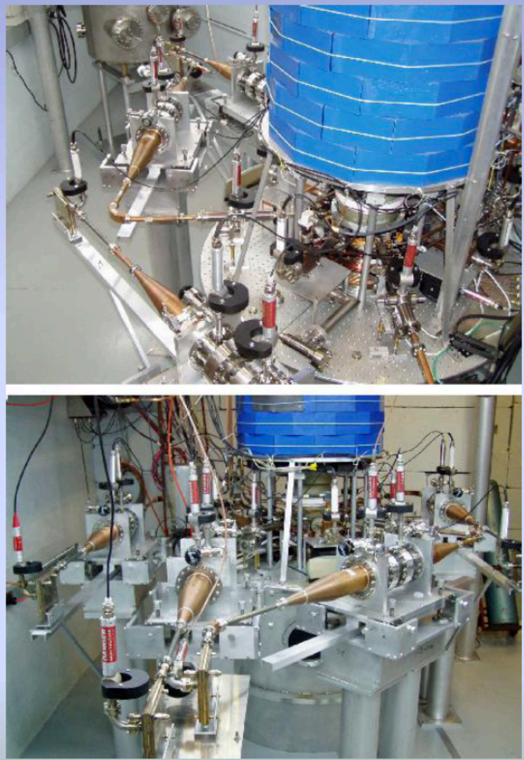
Signal Cavity



on Yale campus . . .

Magnicon

- Output: 1 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.

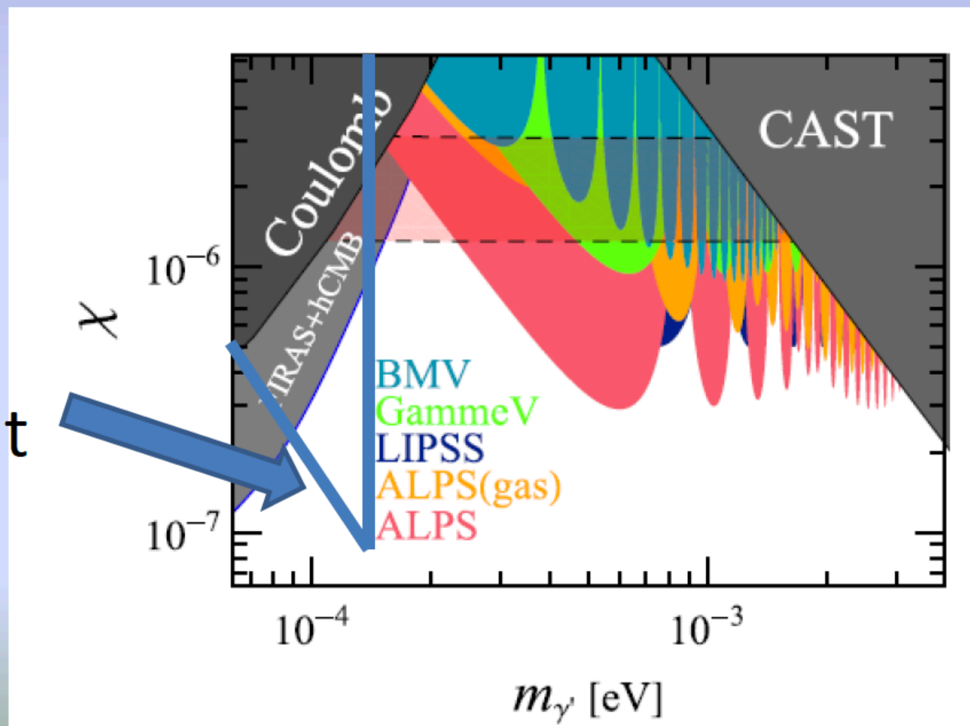


O. A. Nezhevenko et al., IEEE Transactions on Plasma Science, 0093-3813/04, 2004.

Sensitivity to hidden photons

$$P_{trans} = \chi^4 QQ' \frac{m_{\gamma'}^8}{\omega_0^8} |G_{HSP}|^2.$$

Expected result



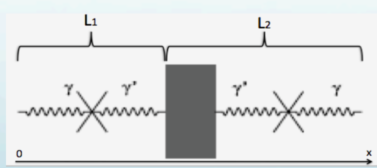
* J. Jaeckel and A. Ringwald, Phys. Lett. B 659 (3) 509, 2008.

TeV gamma rays interact with EBL less than expected – a mystery

we proposed a mechanism by which the flux spectrum of UHE gamma rays could avoid distortion by absorption and Compton scattering in the extragalactic background light (EBL)

R. Anantua and O.K. Baker, PLB (2010)

the arrival directions of UHE cosmic rays are correlated with the position of BL-Lacertae objects (active galactic nuclei pointed at Earth)



$$P_{trans}(\Delta k) = 16\chi^4 \sin^2\left(\frac{\Delta k L_1}{2}\right)\sin^2\left(\frac{\Delta k L_2}{2}\right)$$