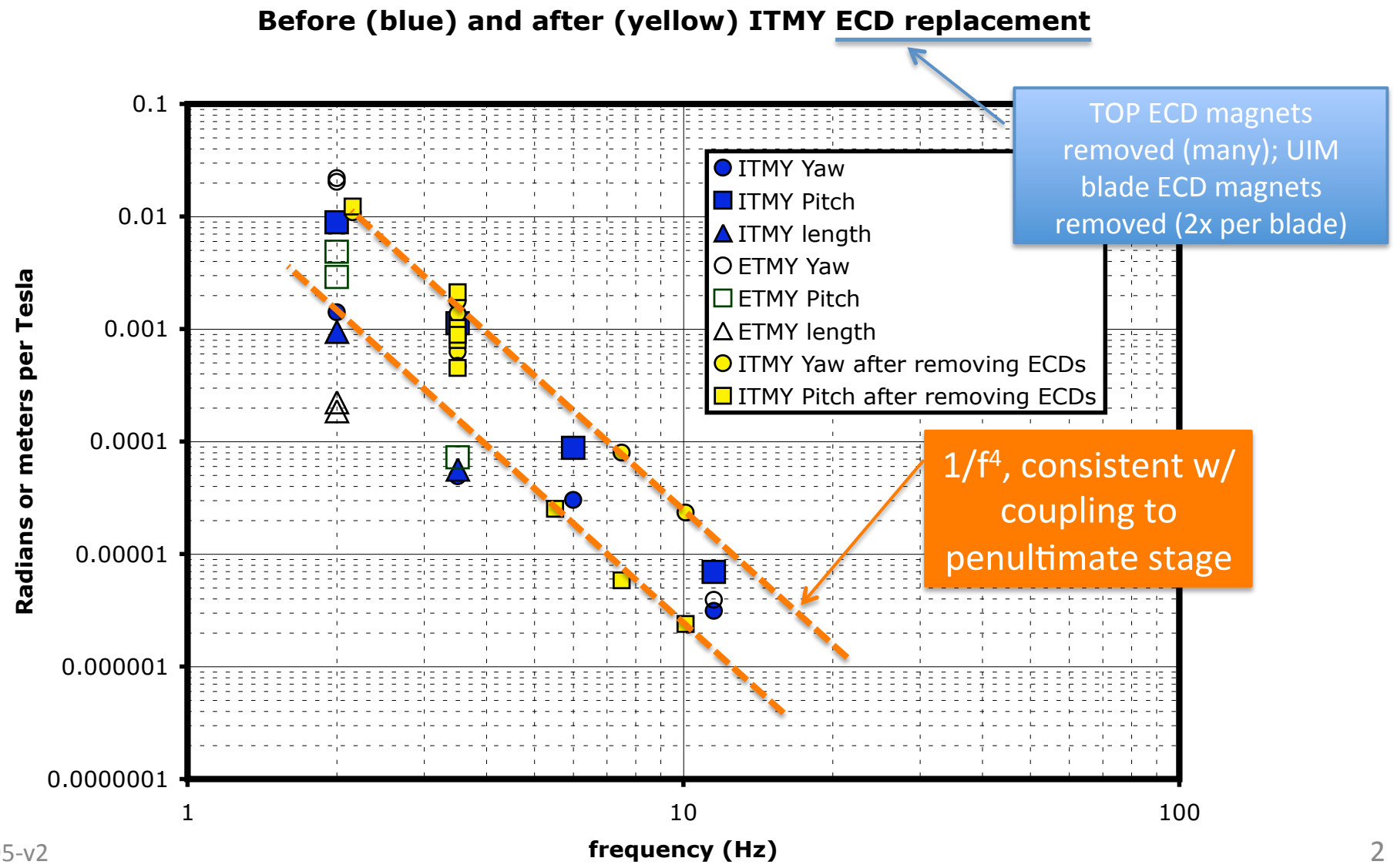
Magnetic Coupling to Test Mass Suspensions

Analysis of R. Schofield's B-field coupling measurements at LHO,

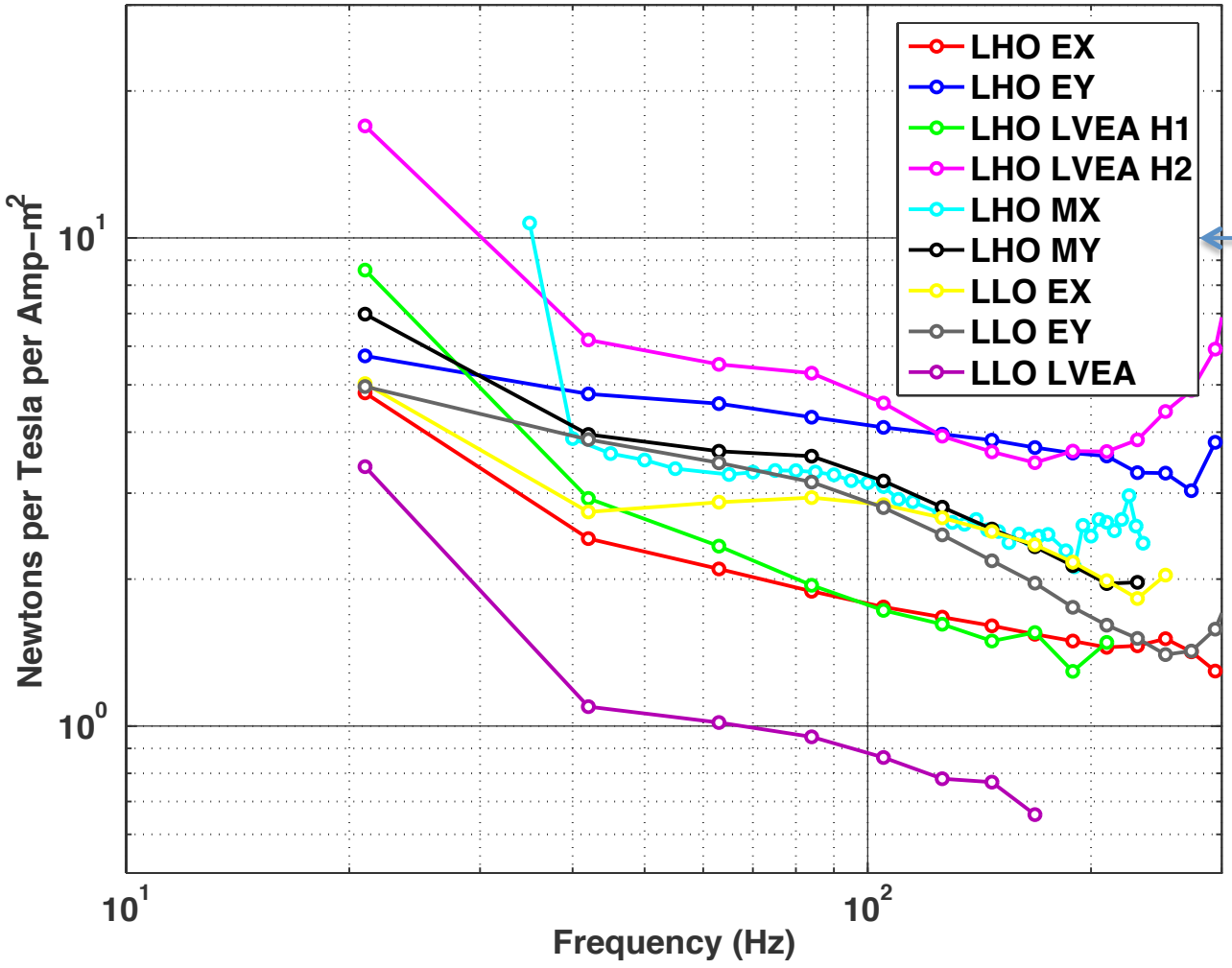
December 2012

Latest Schofield measurements: H1 ITMY (LHO log entry 4944)



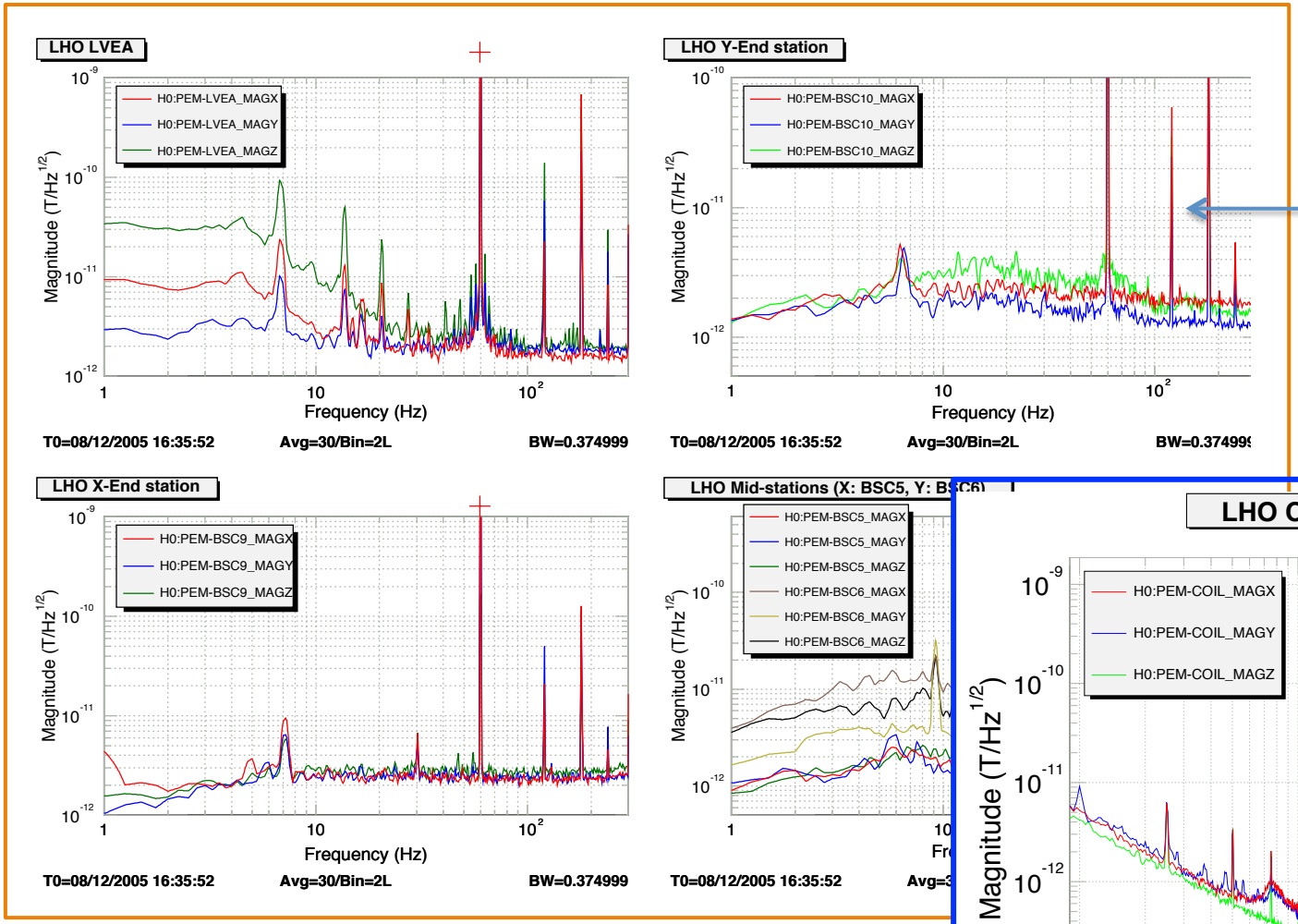
How did we set max PM stage magnet size? (T050271)

Coupling measurements from iLIGO (2005):



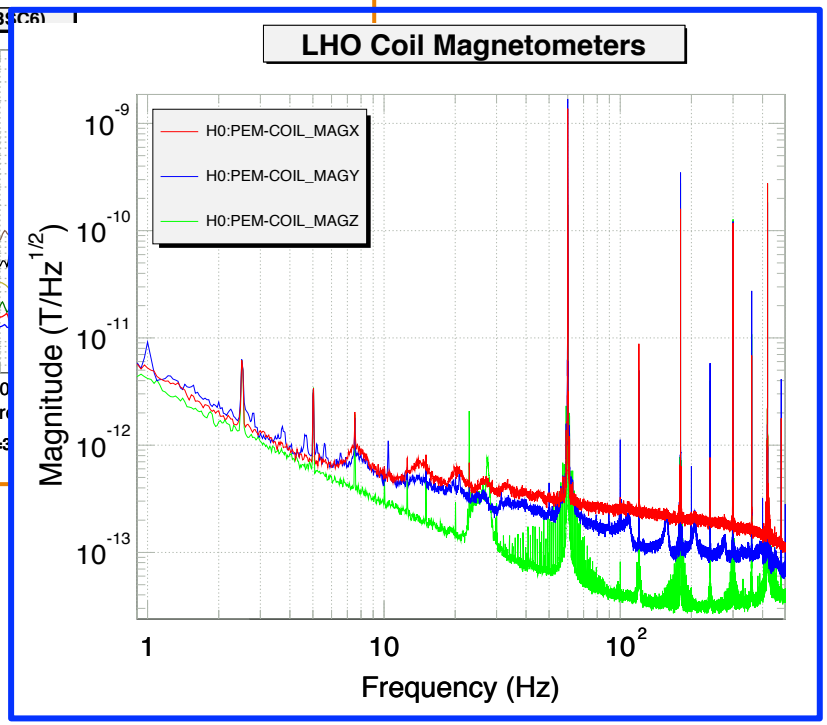
Used 10 N/T/A-m^2 to set limits

Magnetic field noise



Used 10^{-11} T/rtHz to set limits

Vault Coil magnetometer



Flux-gate magnetometer,
Noise floor: 2-3 pT/rtHz

PM stage coupling

- $PM_{force} \rightarrow TM_{displacement}$: T= 2.8e-8 m/N @10 Hz
- Cplg * mu * B_{noise} * T(10 Hz) < 1e-20 m/rtHz
- Mu < 3.6 mA-m^2
- Actual PM magnets:
  - 2mm diam x 6mm long, SmCo
  - Mu = 0.015 A-m^2
  - Paired with a compensation magnet, 30 mm axial separation
  - Yes, magnet Mu is bigger than limit, but effective Mu thought/hoped to be several times smaller due to compensating magnet

Observed coupling

	PM → TM torque-to-angle (SUS model)	Measured coupling	Implied torque coupling	B → Force (12cm lever; normalized by mu)
Pitch	2e-5 rad/N-m	2.5e-6 rad/T	0.125 N-m/T	70 N/T/A-m^2
Yaw	7e-6 rad/N-m	2.5e-5 rad/T	3.5 N-m/T	2000 N/T/A-m^2

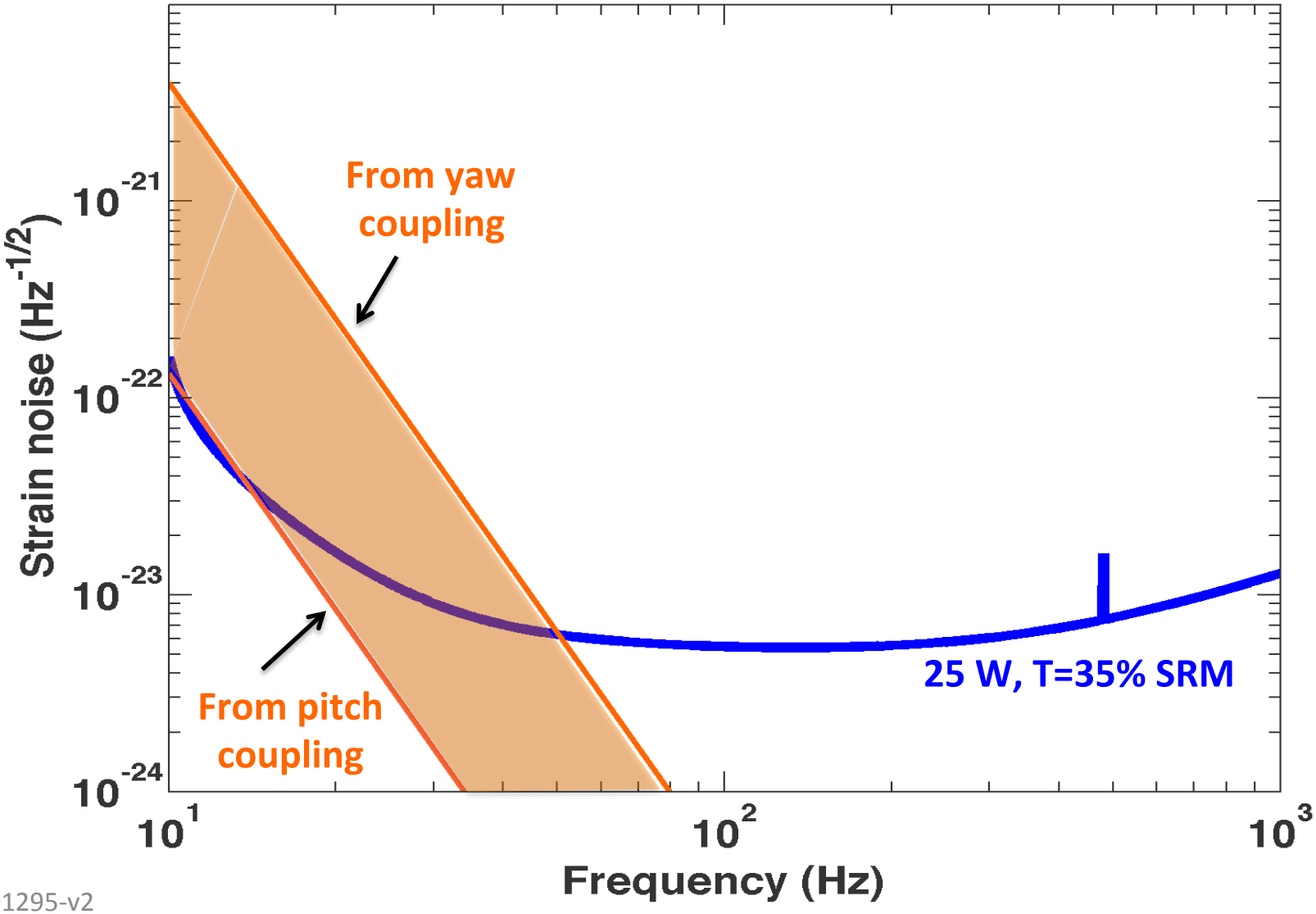
Compare to 10 N/T/A-m^2 used to set limits

- Implied B-field gradients: $\tau = \mathrm{Lever} \times \mu \times \nabla B$
  - Pitch: (1/B)dB/dx = 70 m^{-1} (1.5 cm scale)
  - Yaw: (1/B)dB/dx = 2000 m^{-1} (1/2 mm scale ??)

Extrapolation to longitudinal motion

- For force applied at PM magnets, relation between displacement and angle (above 5 Hz):
  - Pitch: 0.01 m/rad
  - Yaw: 0.03 m/rad
- Potential longitudinal coupling, inferred from measured pit/yaw coupling, is thus, @10 Hz:
  - 7.5e-7 m/Tesla, from yaw measurement
  - 2.5e-8 m/Tesla, from pitch measurement

Strain noise, assuming 10 pT/rtHz



Next steps

- aOSEM holders on the reaction chain PM stage (L2) will be replaced with slit parts (reduce eddy currents)
  - H1 ITMY: can be replaced in-situ, but may wait for an opportune time
  - L1 ITMX: parts being prepared now
- Prospect for measuring Longitudinal coupling
  - Applied fields are 'tens of micro-Tesla'
  - Longitudinal motion of 10^{-12} – few 10^{-11} meters
  - H2OAT sensitivity at 10 Hz: ~10^{-10} m/rtHz
  - L1 will have Michelson sensing, ~10^{-16} m/rtHz or better