Seismic Isolation & Alignment for Advanced LIGO: Update on Stanford ETF & New HAM baseline

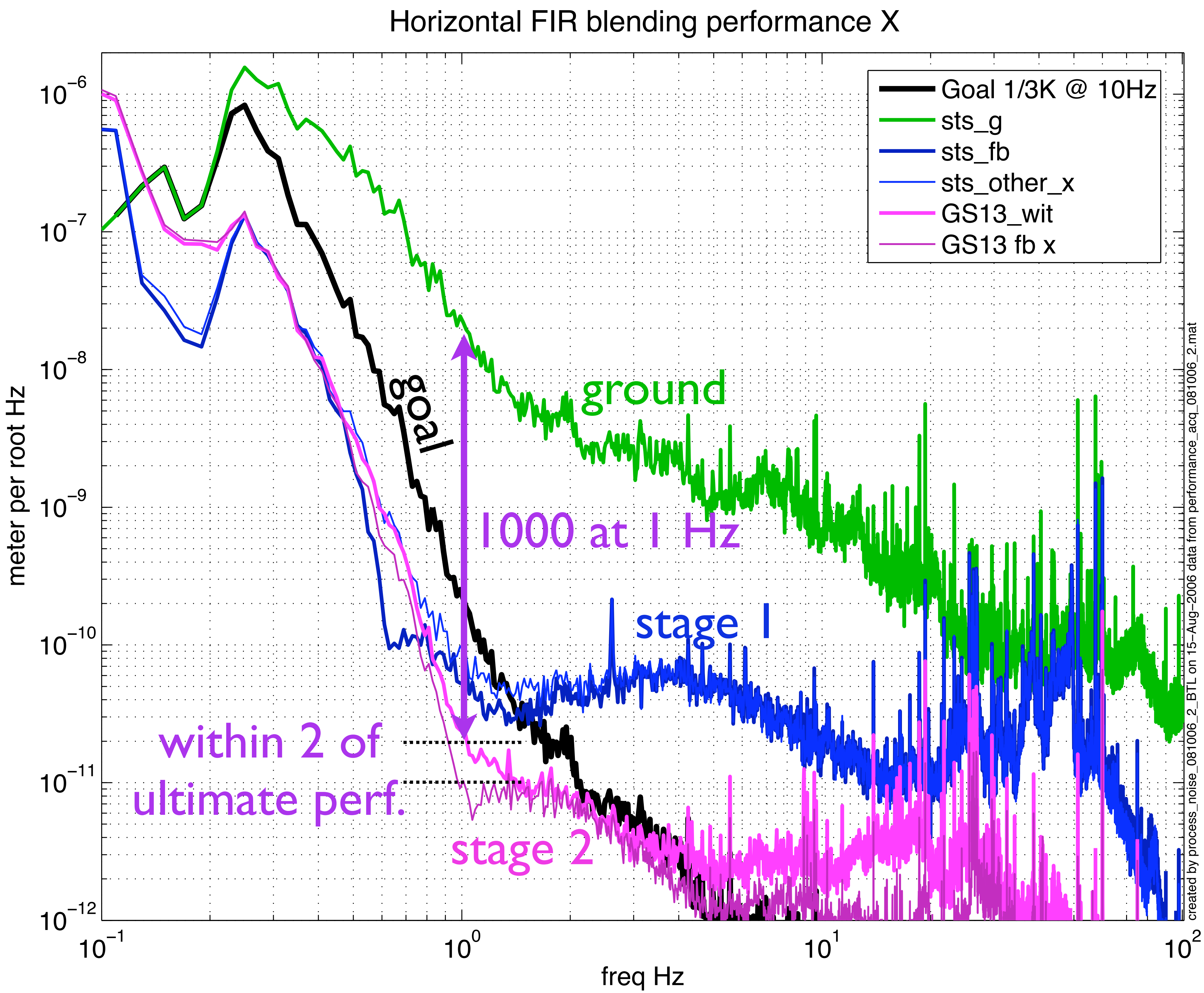
presented by Brian Lantz for the SEI team,
LSC meeting, August 16, 2006

Progress on Seismic Systems for Advanced LIGO

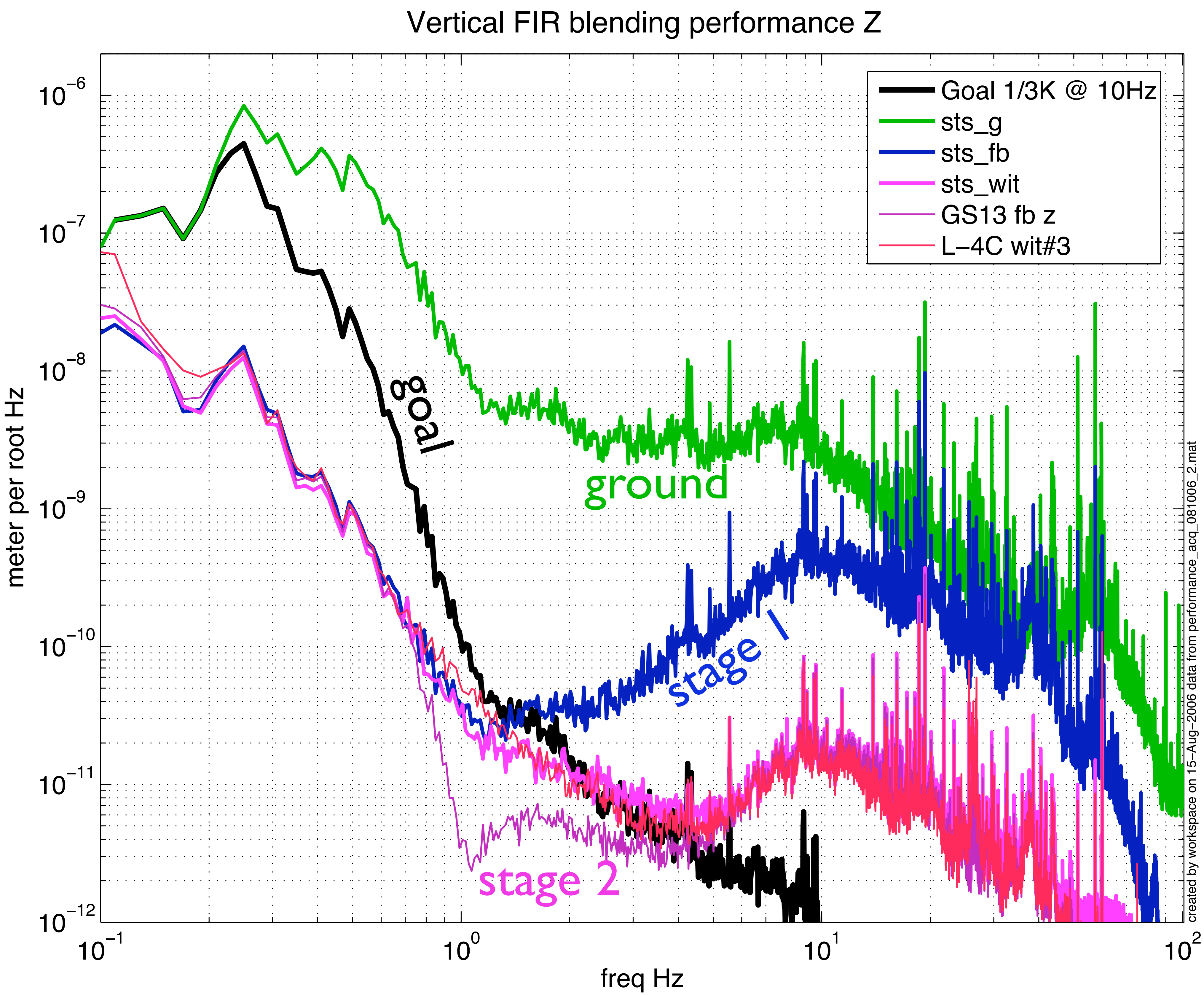
BSC at 1 Hz BSC at 10 Hz HAM

- Improved the sensors on stage 2.
- Improved the 1 Hz translation by reducing the tip/tilt.
- 1 Hz isolation is about 1000 (x10 better than req.)
- 1 Hz motion is 2×10^{-11} m/√Hz, (within 2 of motion req.)
- Demonstrated ultimate sensor performance for Advanced LIGO

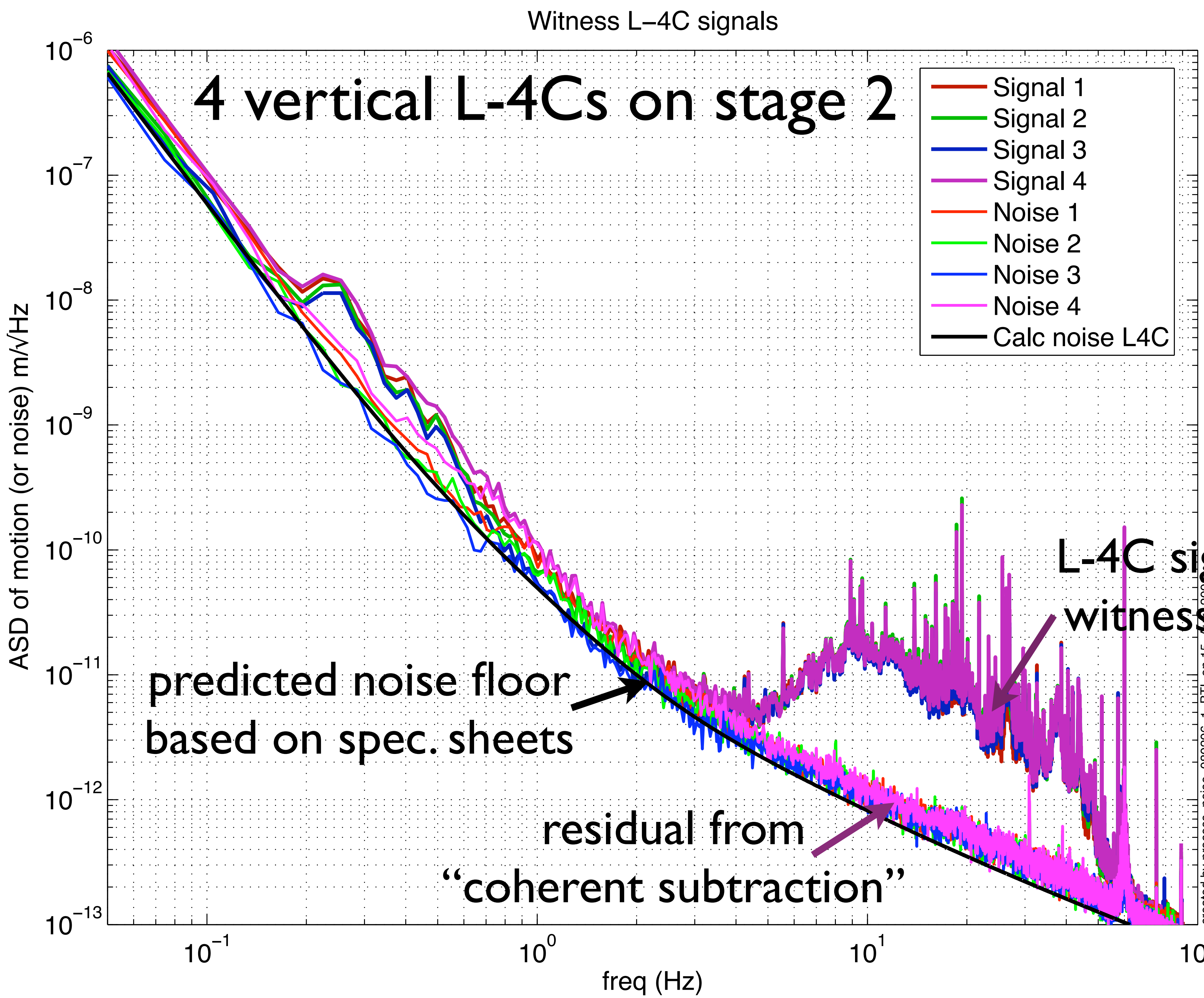
ETF performance: Horizontal



ETF Performance: Vertical

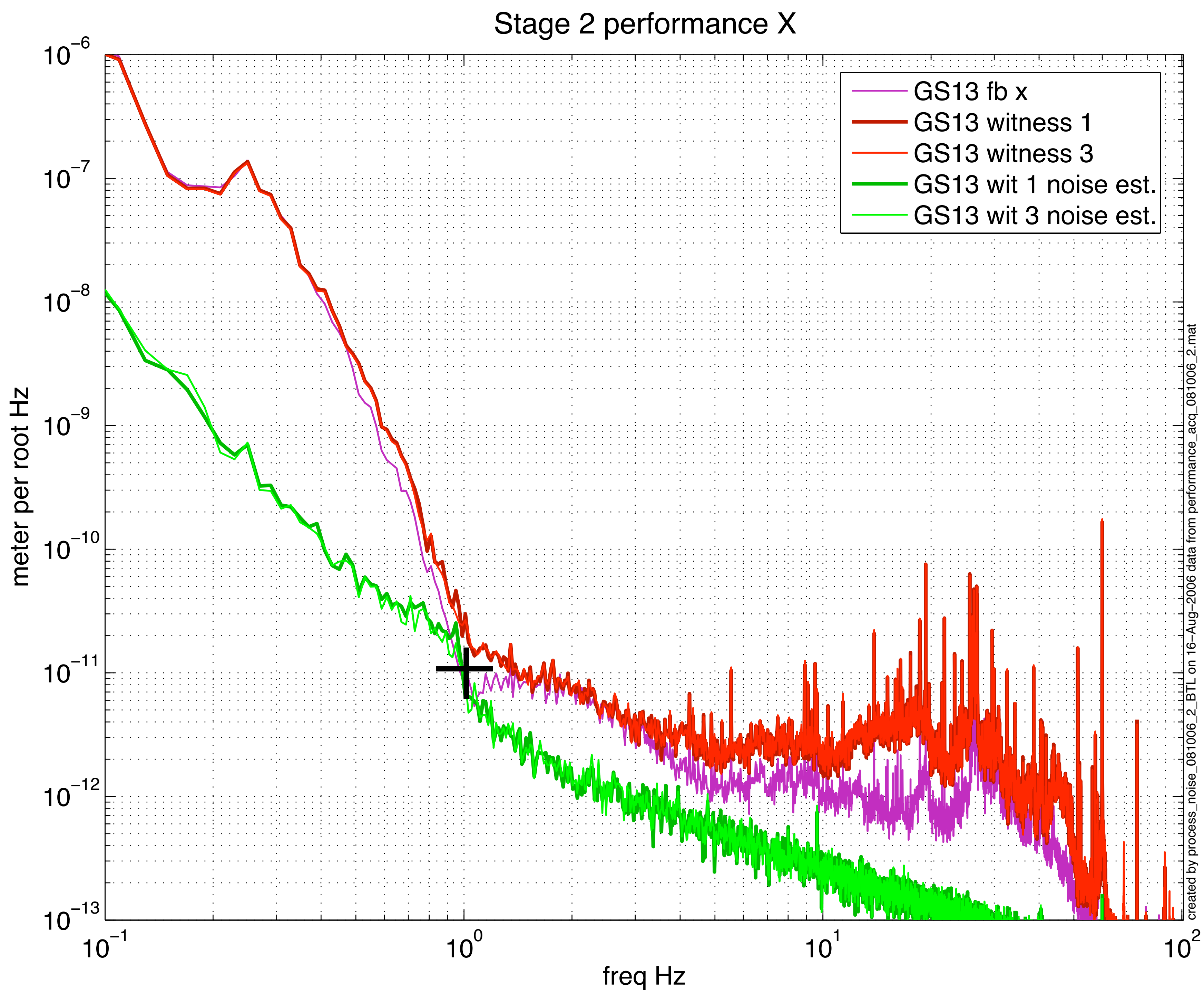


Direct measurement of L-4C noise floor



Noise floor of the GS-13

- Inertial feedback sensor for
  stage 2 of the BSC platform and for the HAM platform.
- Has new low-noise preamp (Jay and Brian).



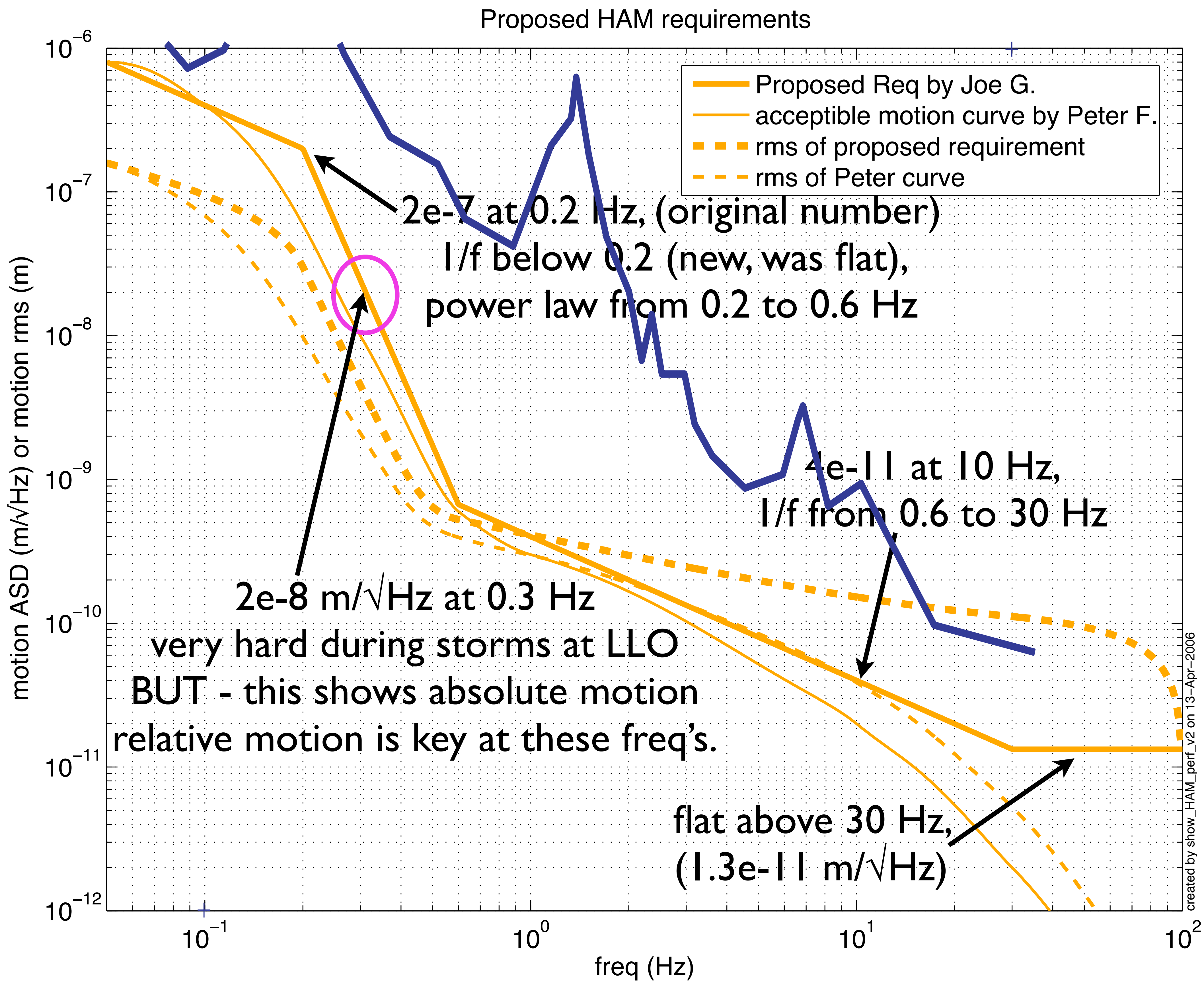
Single Stage HAM for Advanced LIGO

Mechanical design by Corwin Hardham

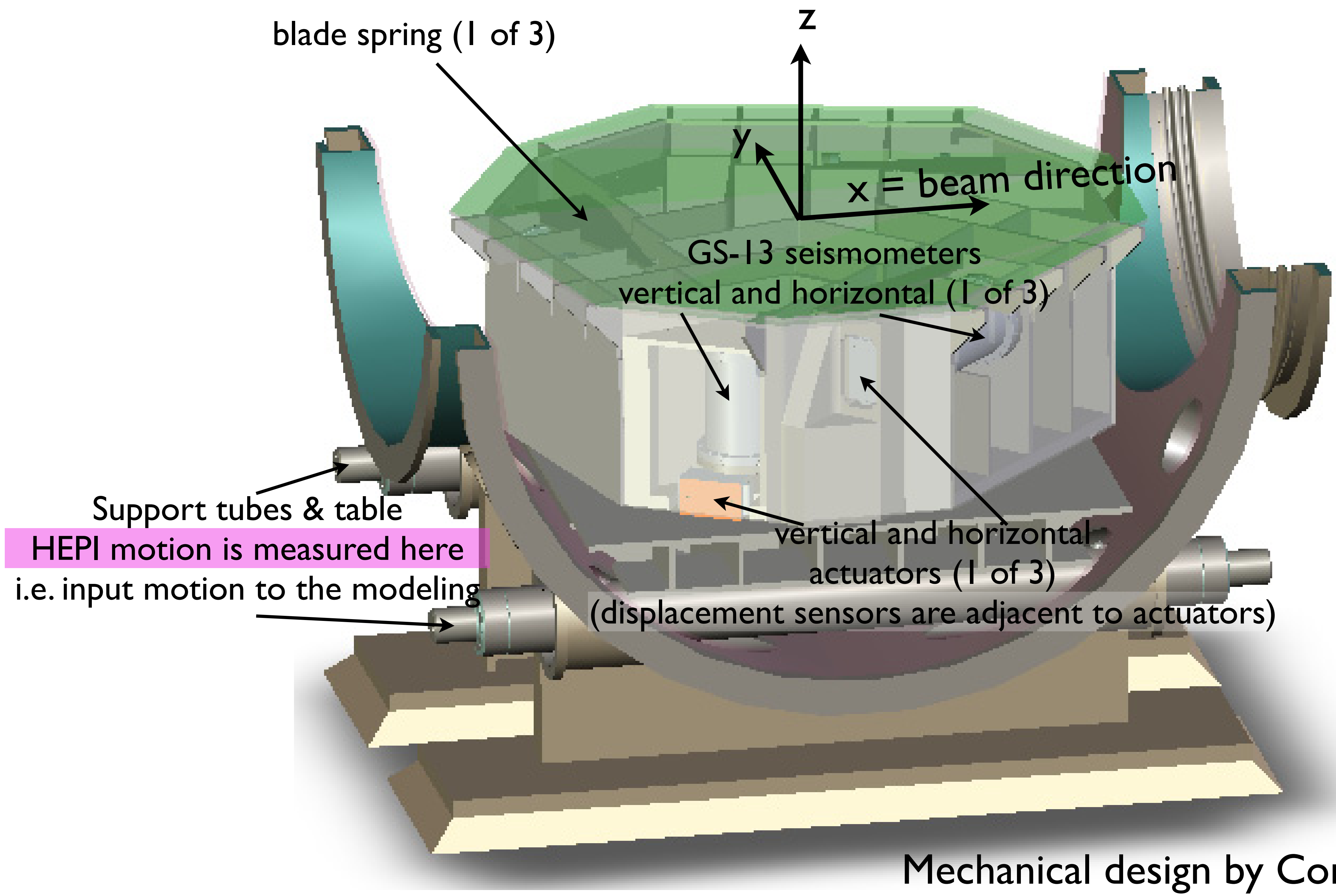
Outline

- Calculations for optical motion in HAMs has been revised New requirements allow more motion.
- Review in April 2006 of new requirements,
- Committee adopted a new, simpler platform concept as the Baseline for HAM chamber Isolation and Alignment for Advanced LIGO.
- Mechanical System
- Control System
- Estimates of Performance

Requirements

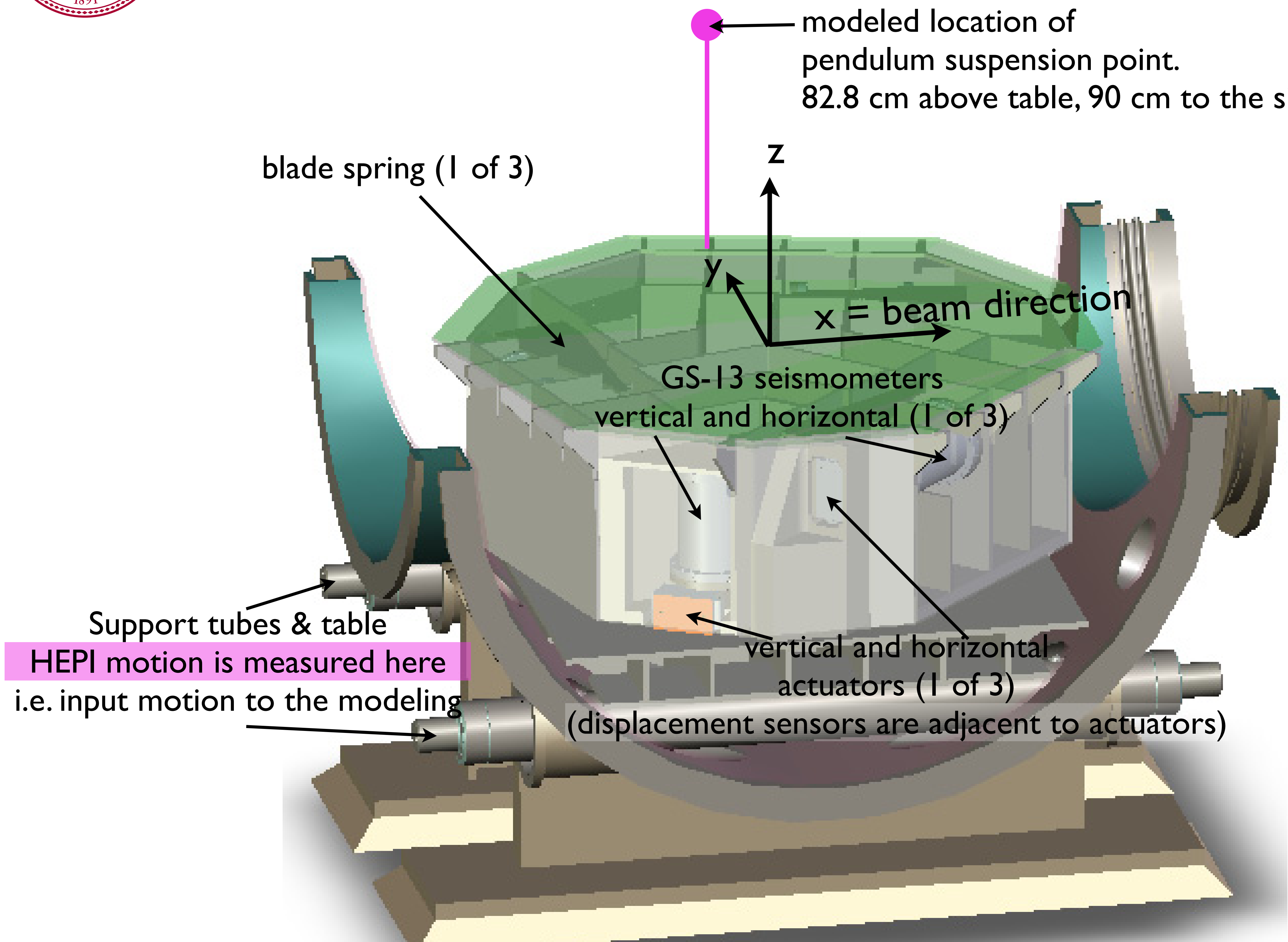


Drawing of Single Stage HAM



Mechanical design by Corwin Hardham

Drawing of Single Stage HAM



Mechanical design by Corwin Hardham

Various parameters used in the HAM model

parameters of the 1 stage HAM isolation system

mass of stage (kg, structure)	1400
mass from Corwin (for comparison)	1166
trim mass (kg)	100
payload total (kg)	510
payload fixed (kg)	435
payload suspended (kg)	75
total stage 1 fixed mass (kg)	1935
Ixx (kg-m^2) (for 1935 kg)	759
Rad Gyr X (m)	0.627
Iyy (kg-m^2)	797
Rad Gyr Y (m)	
Izz (kg-m^2)	770
Rad Gyr Z (m)	0.631
f0 - X (Hz)	1.22
f0 - Z (Hz)	1.83
f0 -rX (Hz)	1.04
f0 - rZ (Hz)	0.984
horizontal stiffness (N/m)	1.10E+05
vertical stiffness (N/m)	2.54E+05
rX stiffness (N-m/rad)	3.33E+04
rZ stiffness (N-m/rad)	2.93E+04
blade stiffness (N/m)	8.60E+04
blade length (m)	0.474
blade width (m)	0.237
blade thickness (m)	0.0107
tip radius (m)	0.512
effective rod length (m)	0.132
height of cg above LZMP (m)	0.048

(tip radius is the distance from center of table out to the flexures which are located at the tips of the blade springs - important for rotational stiffness)

Stiffness and Compliance

DC stiffness is similar to existing HAM platform

stiffness defined as F = K*X

compliance is X = C*F

F in N or N-m, X in m or radians

```
>> 1./diag(comp)
ans =
   1.1046e+05
   1.1046e+05
   2.5415e+05
        33371
        33371
        29318
```

Proposed Single Stage HAM

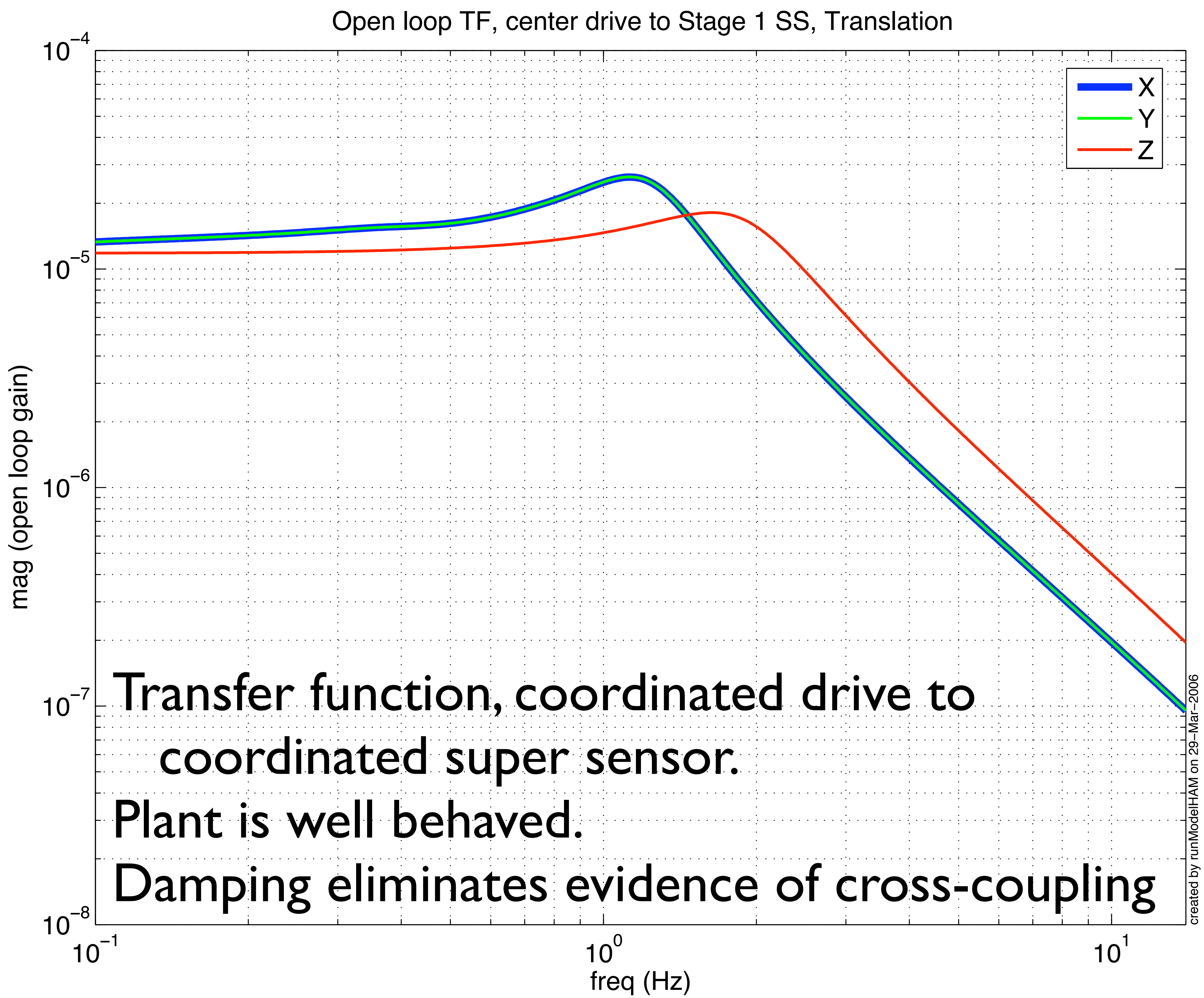
‘Stiffness’ for x, y, z, rx, ry, rz (N/m or N-m/rad)

```
>> 1./diag(HAM_stack_comp)
ans =
        98406
   1.2005e+05
   3.3014e+05
        76138
        32862
        49010
```

Current HAM stack

based on Hytec model

Damped plant - translation

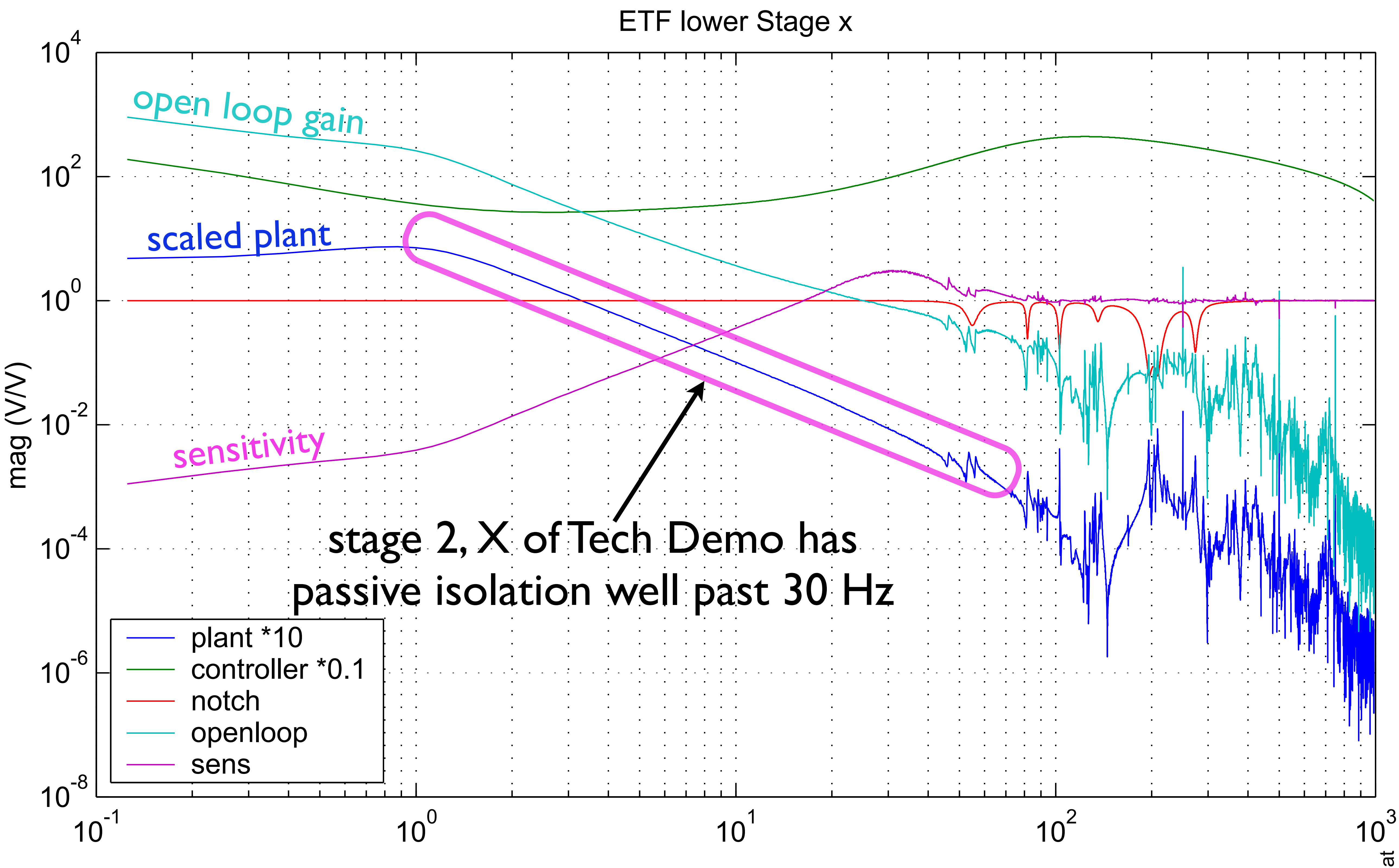


Transfer function, coordinated drive to coordinated super sensor.

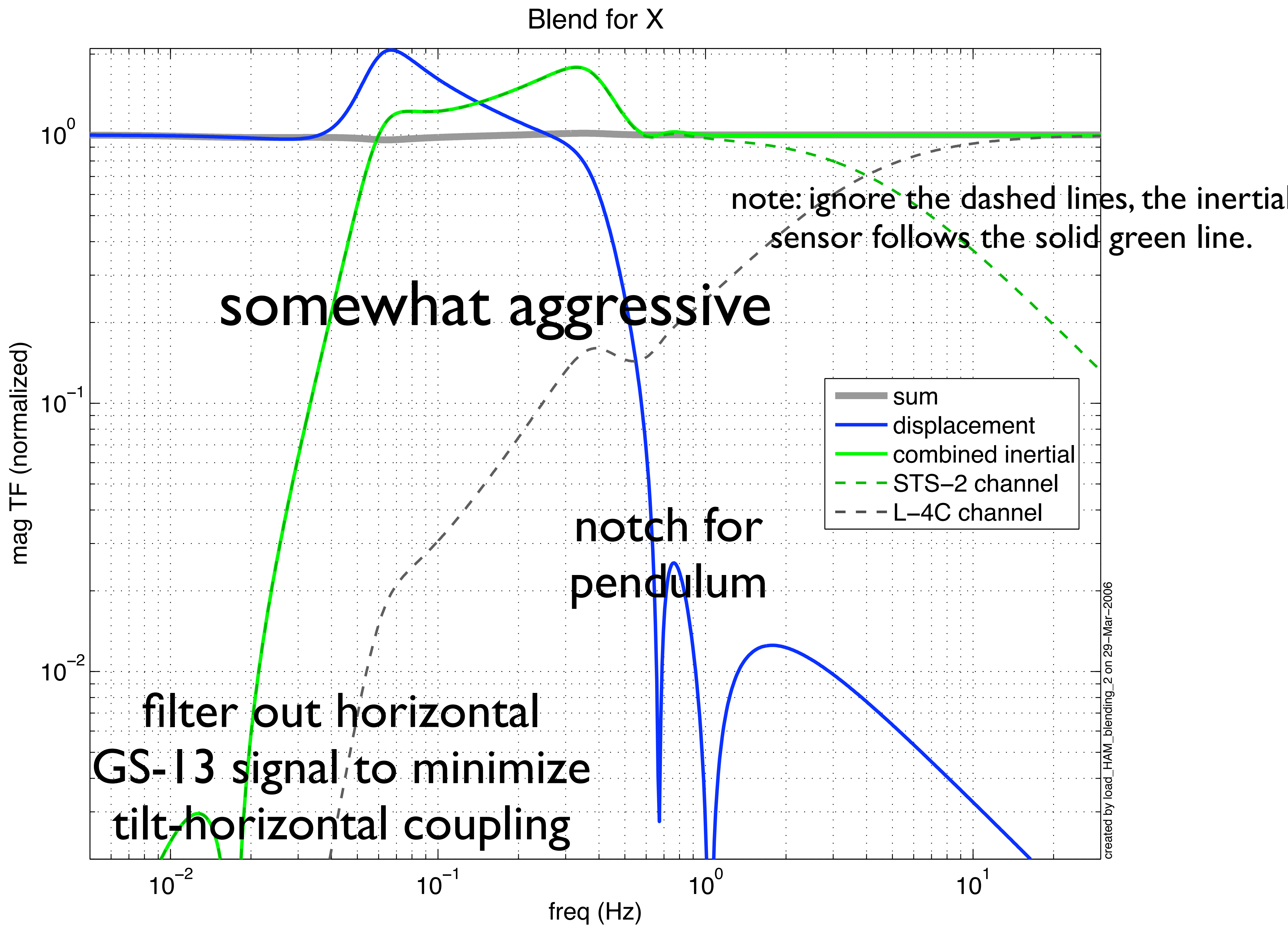
Plant is well behaved.

Damping eliminates evidence of cross-coupling

Tech Demo experience
Passive Isolation

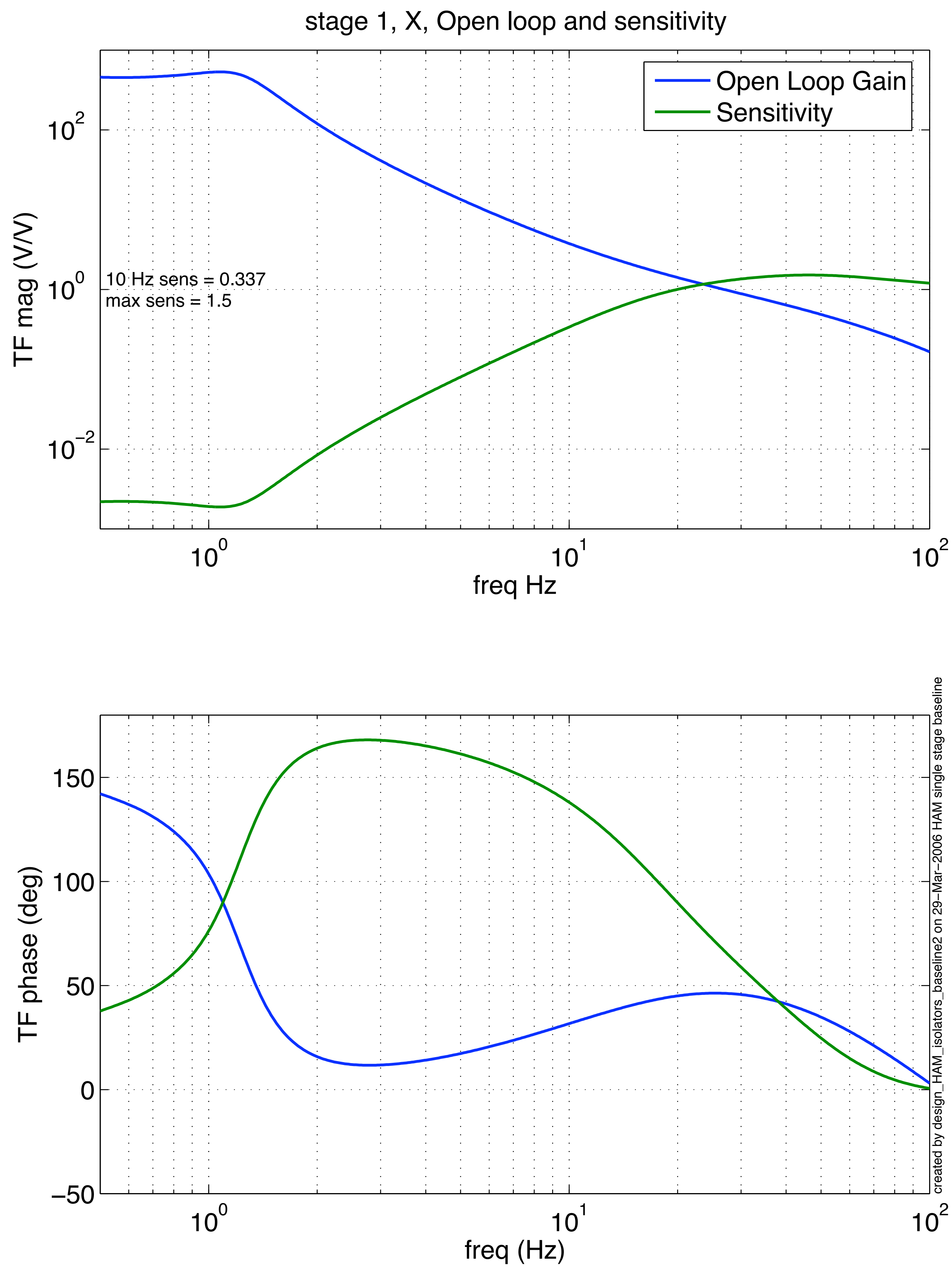


Blending for X & Y

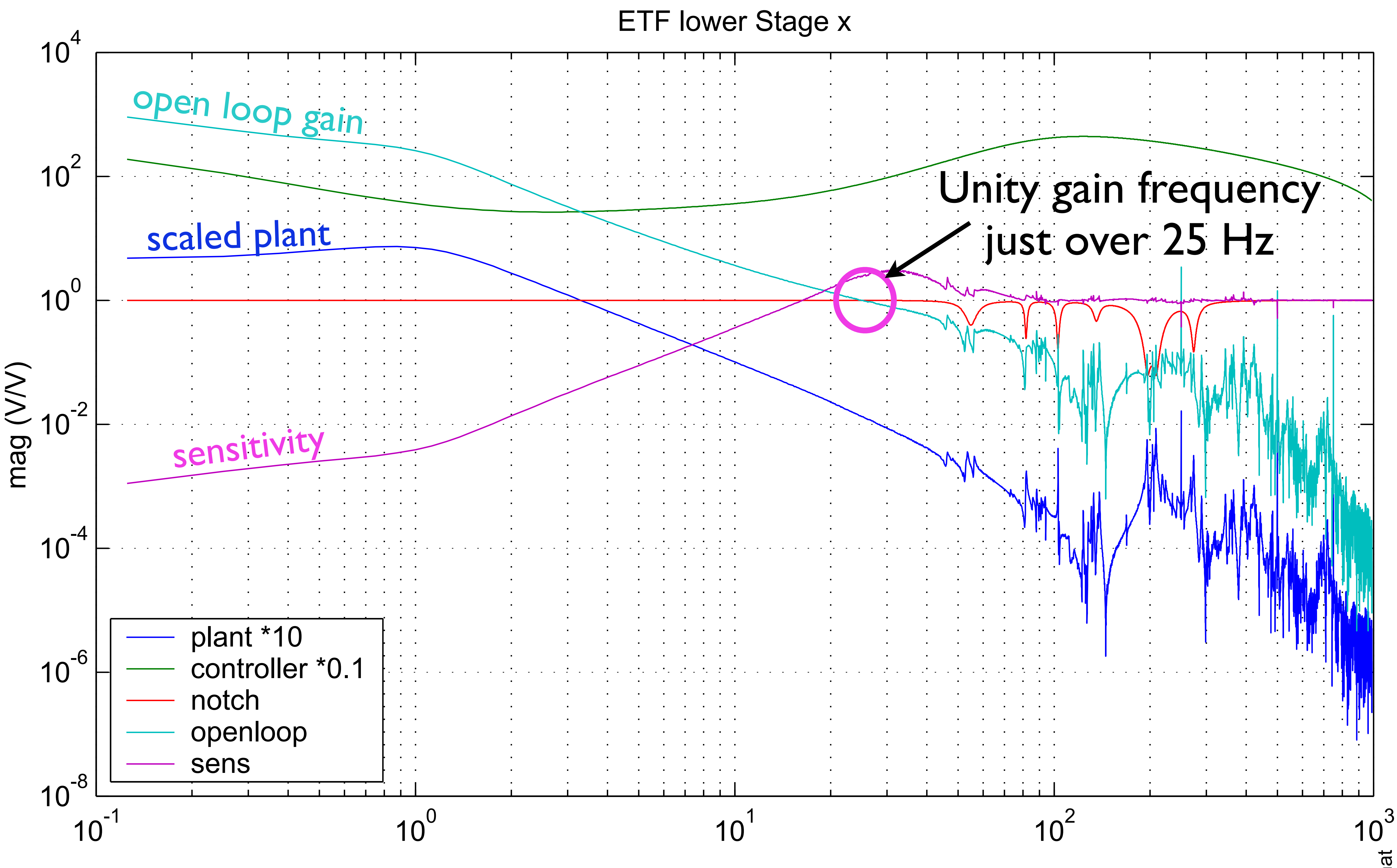


Isolation Loop, x & y

- Isolation factor of 3 at 10 Hz
- Unity gain at 27 Hz
- Like the Tech Demo
- All DOF are about the same.



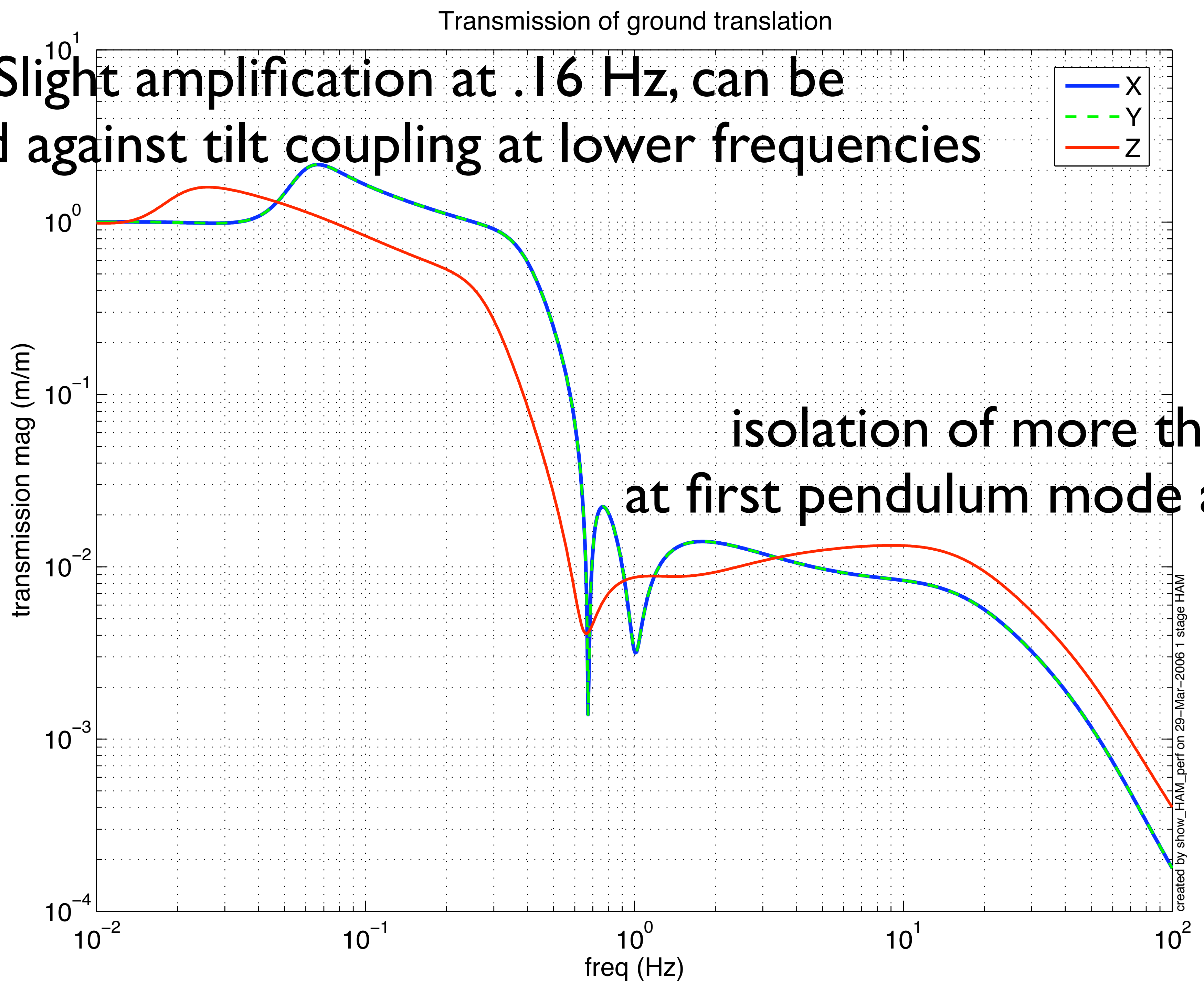
Tech Demo experience
Active Isolation



Coupling of HEPI motion

Transmission of translational input motion
HEPI motion -> table cg motion

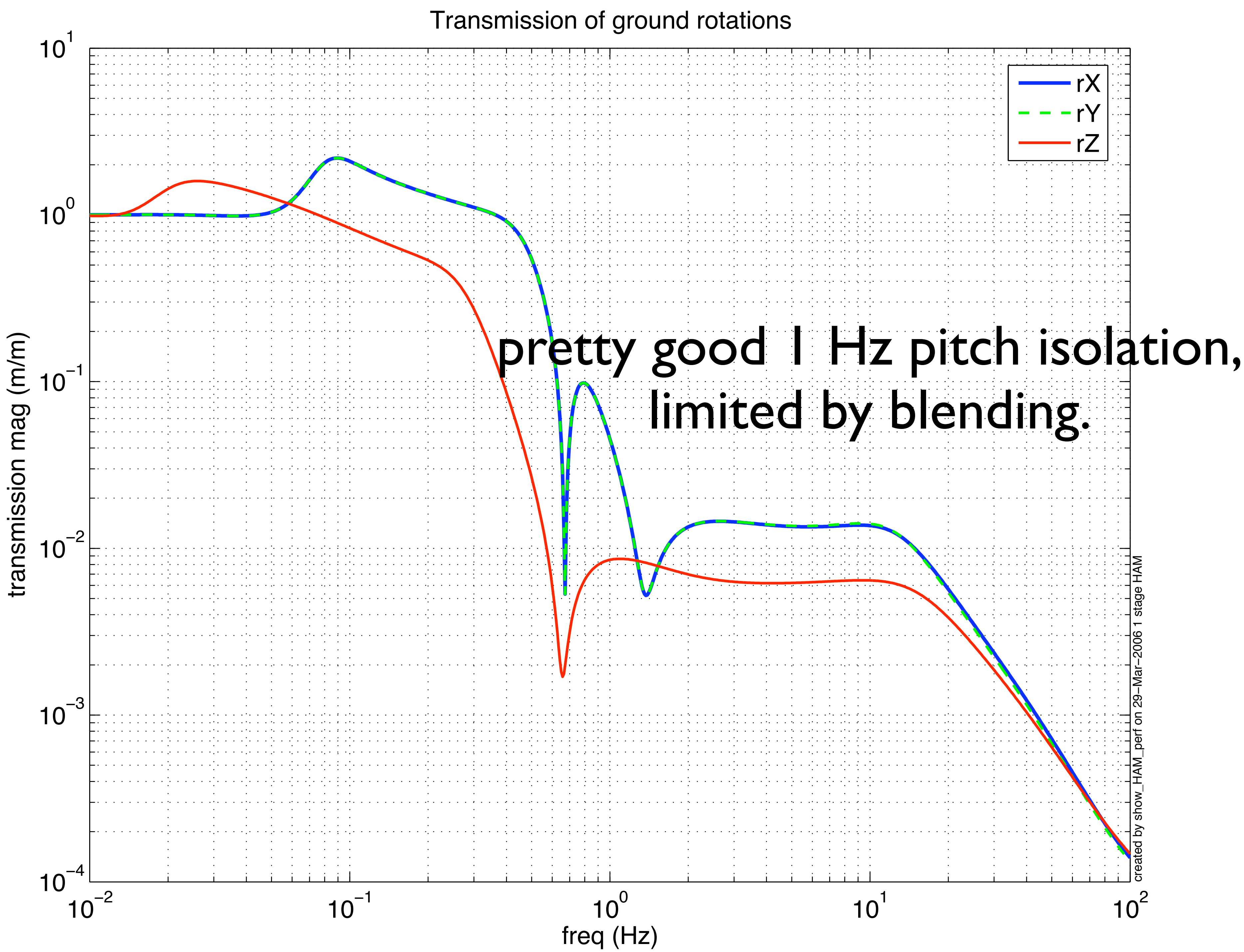
Slight amplification at .16 Hz, can be traded against tilt coupling at lower frequencies



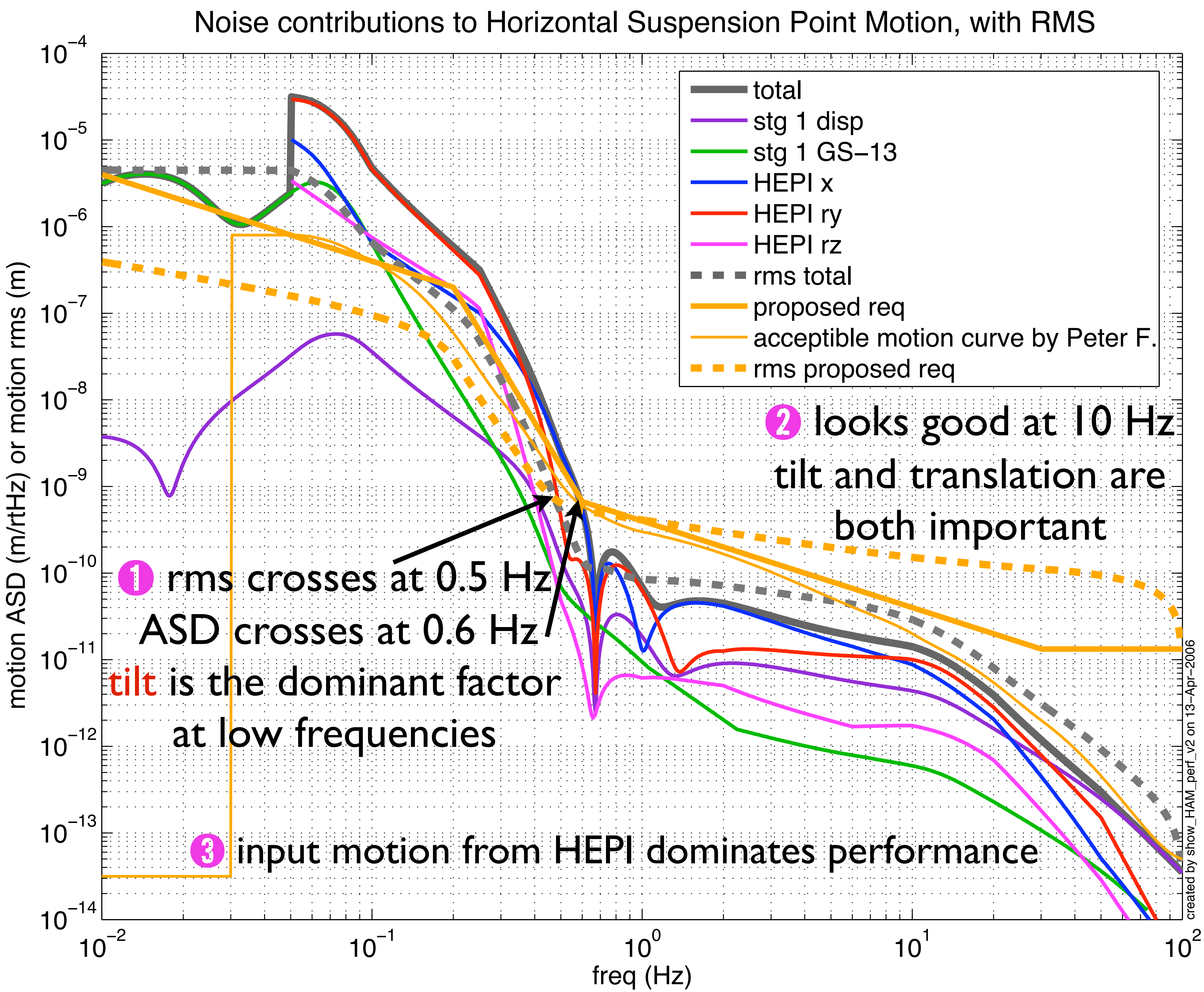
isolation of more than 50 at first pendulum mode and above

Coupling of HEPI motion

Transmission of rotational input motion
HEPI motion -> table cg motion

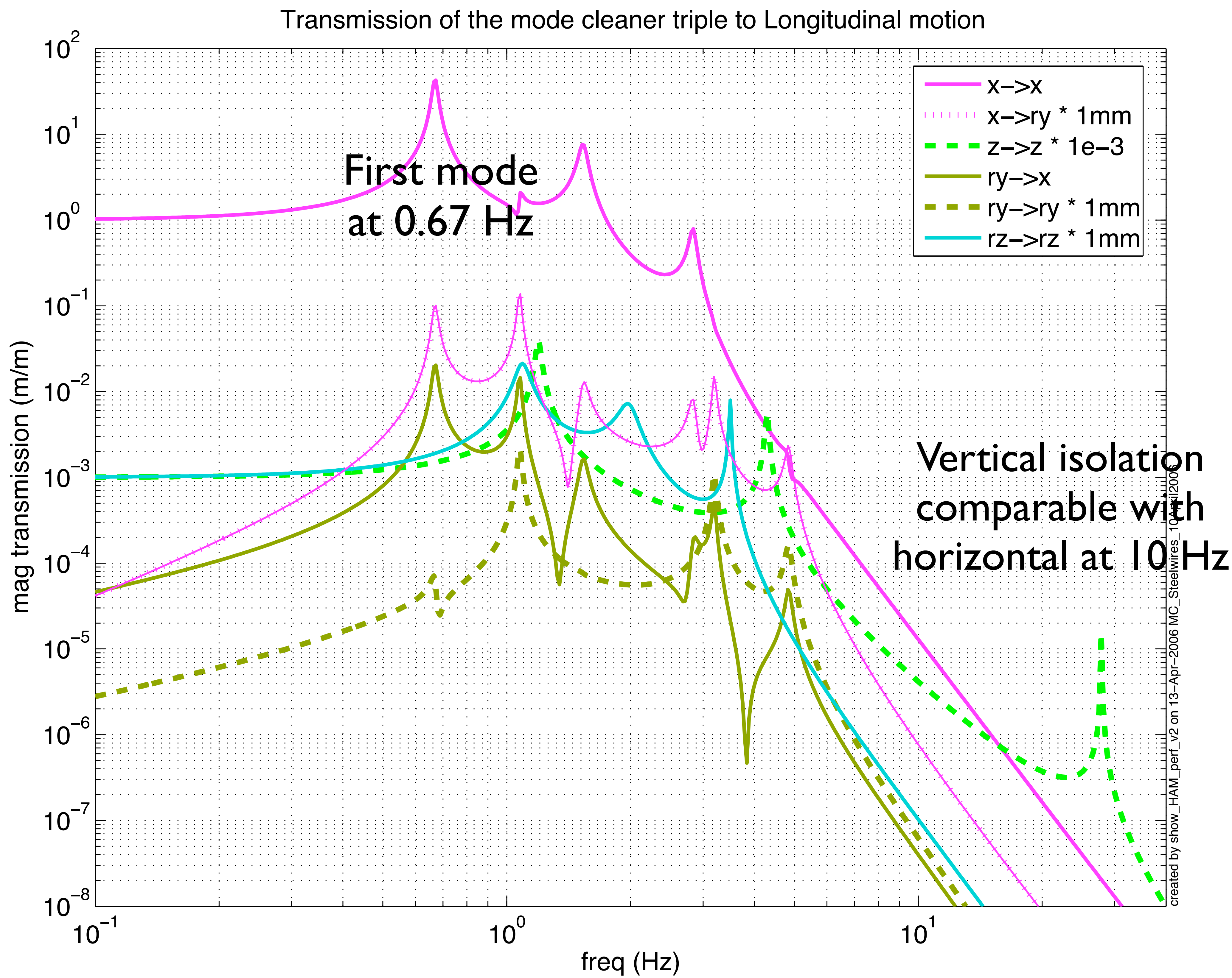


HAM performance

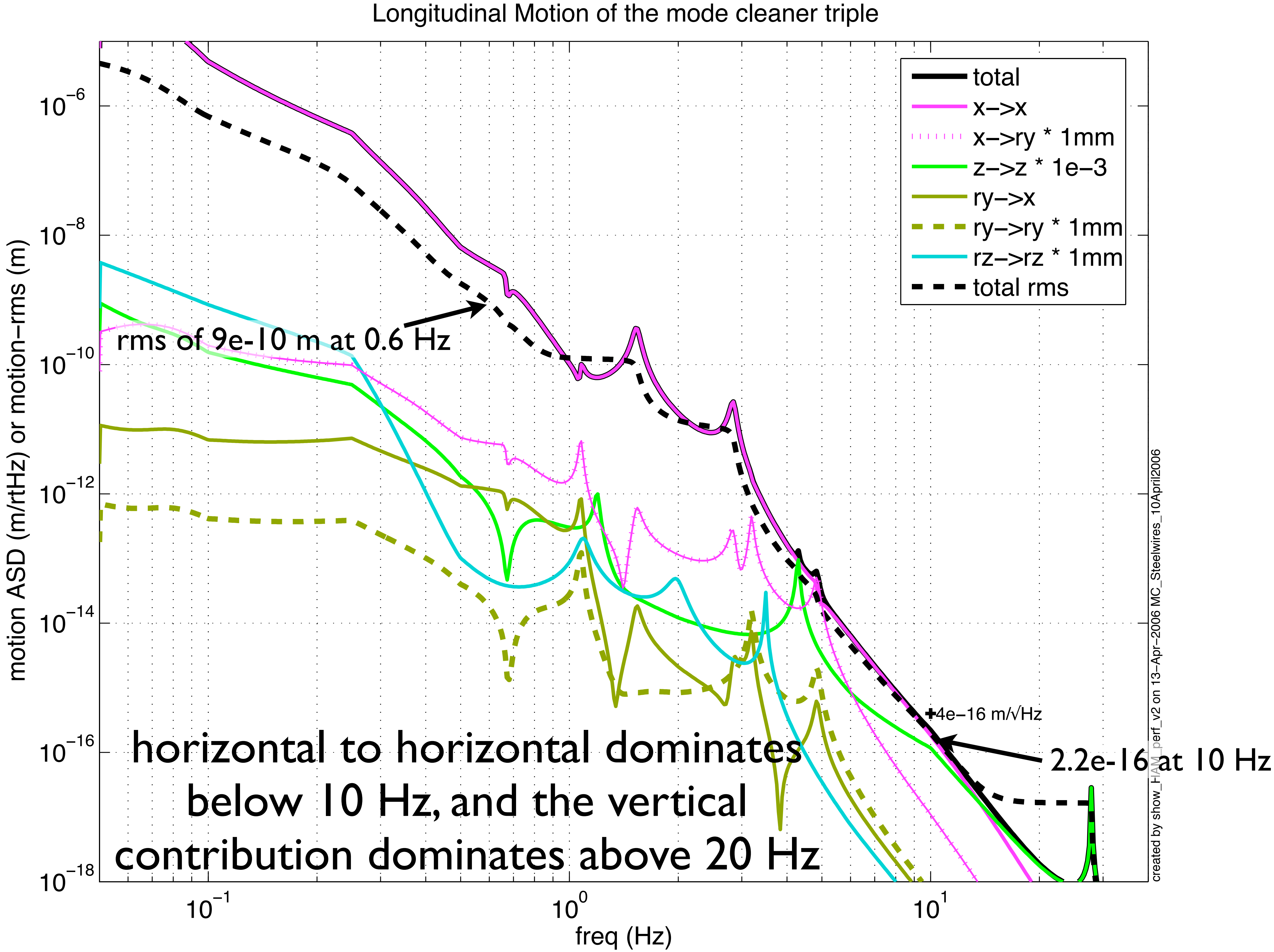


Pendulum Isolation, beam direction

Assume a triple pendulum with steel wires, from Norna, April 2006



Test mass motion, beam direction



Conclusions

- Confident in 1 Hz performance for Advance LIGO
- Single stage HAM with these control laws provides good performance.
- Most of the performance claims have been demonstrated with the Technology Demonstrator.
- 10 Hz ASD and 0.6 Hz rms meet new requirements.
- More work needed below 0.6 Hz (ASD and rms) (common mode rejection, LSC loop gain, try FIR isoaltion filters, better HEPI tilt control, better tilt sensors).
- Single stage is easier to build, commission, and maintain.