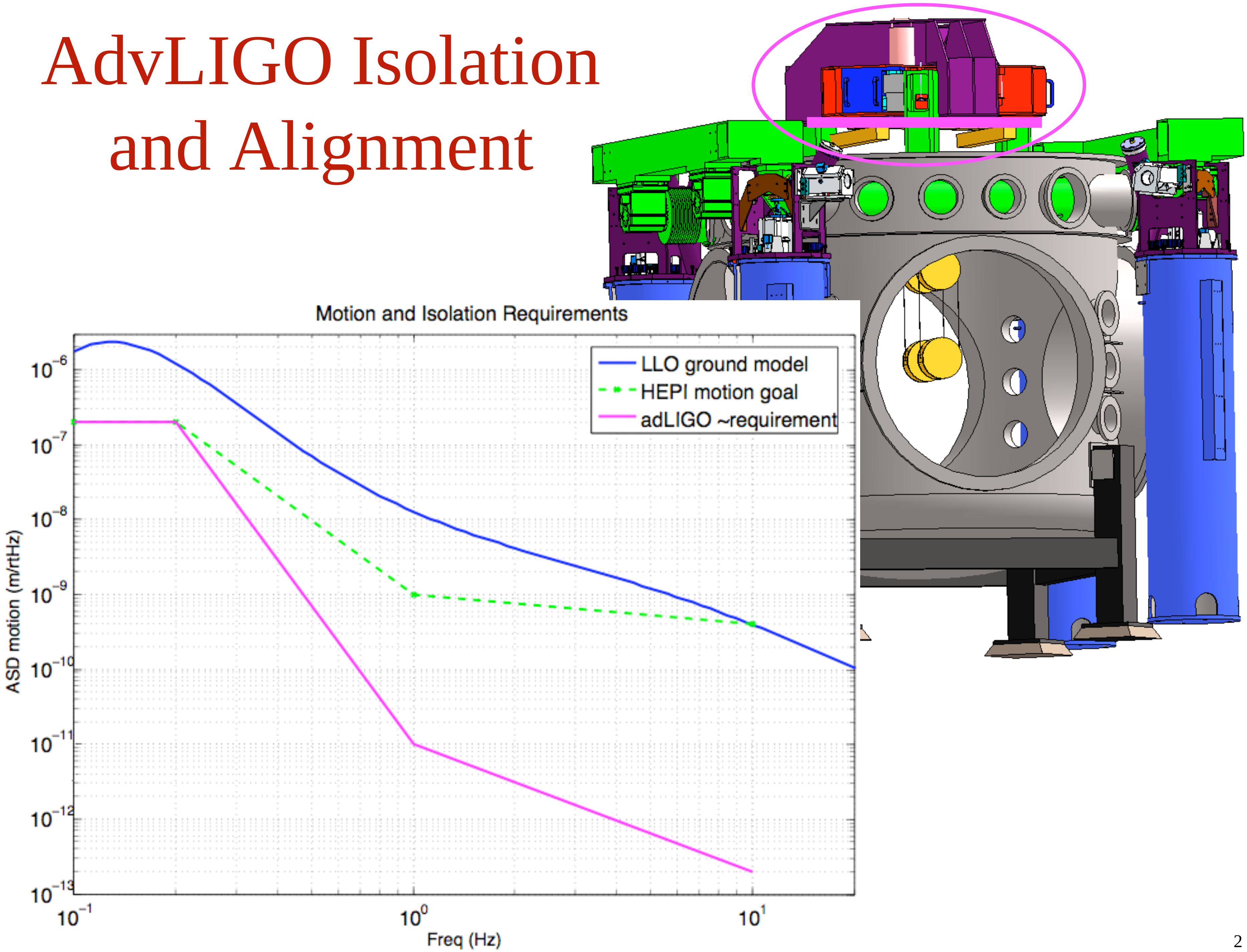
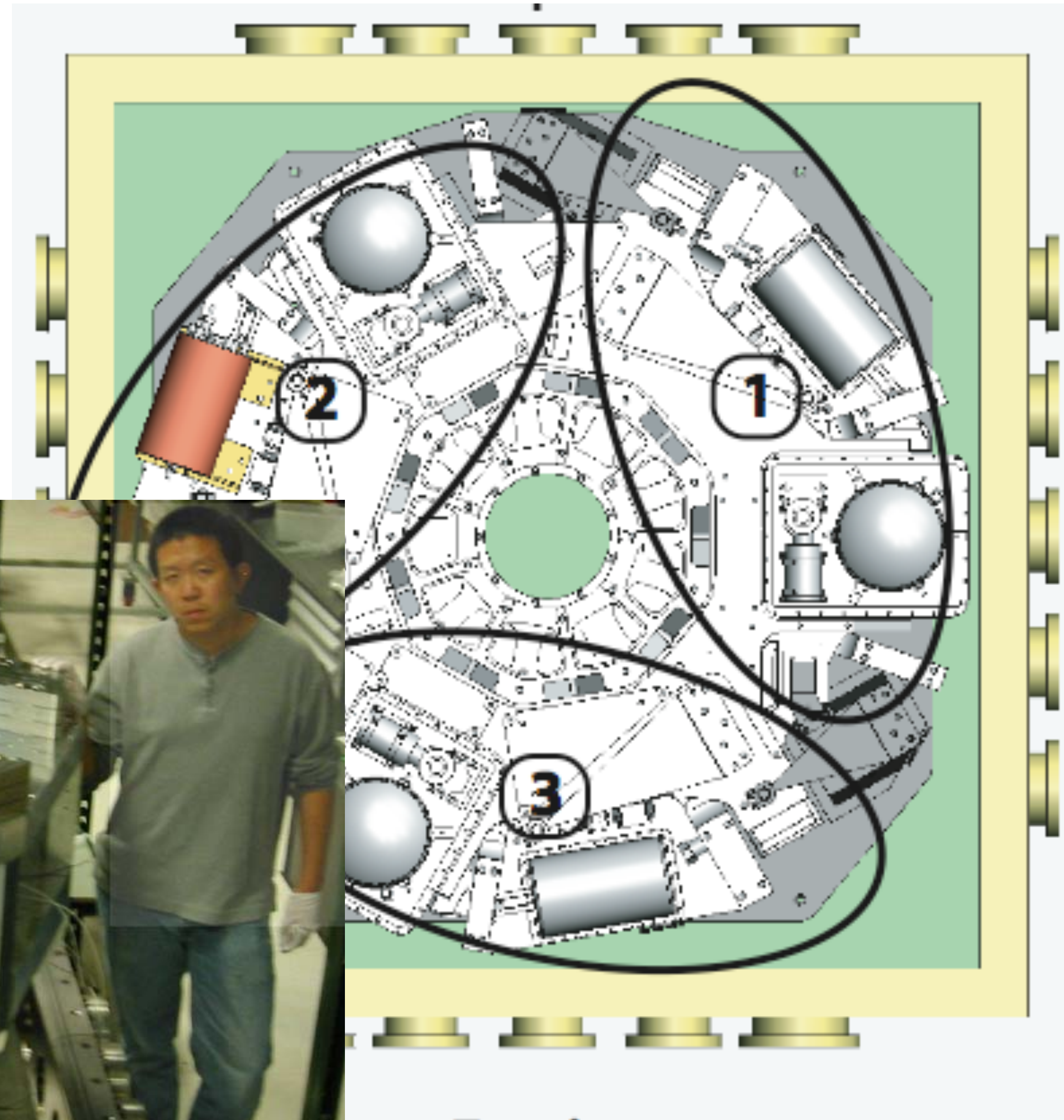
Progress in Seismic Isolation and Alignment on the Technology Demonstrator at the Stanford ETF

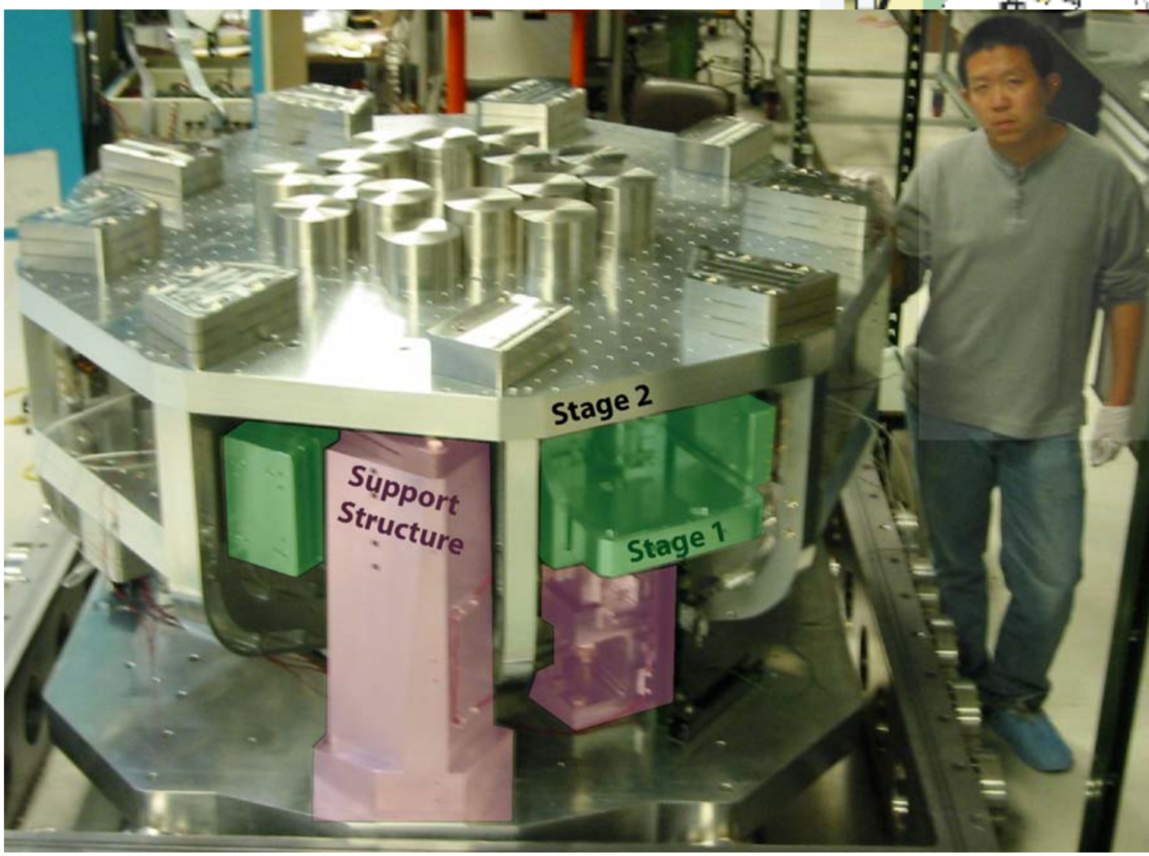
Brian Lantz and Wensheng Hua, for the
Advanced LIGO SEI team

AdvLIGO Isolation and Alignment



Views of the Technology Demonstrator





Top view

Control Steps

1. Close damping loops in 6 DOF for each stage.

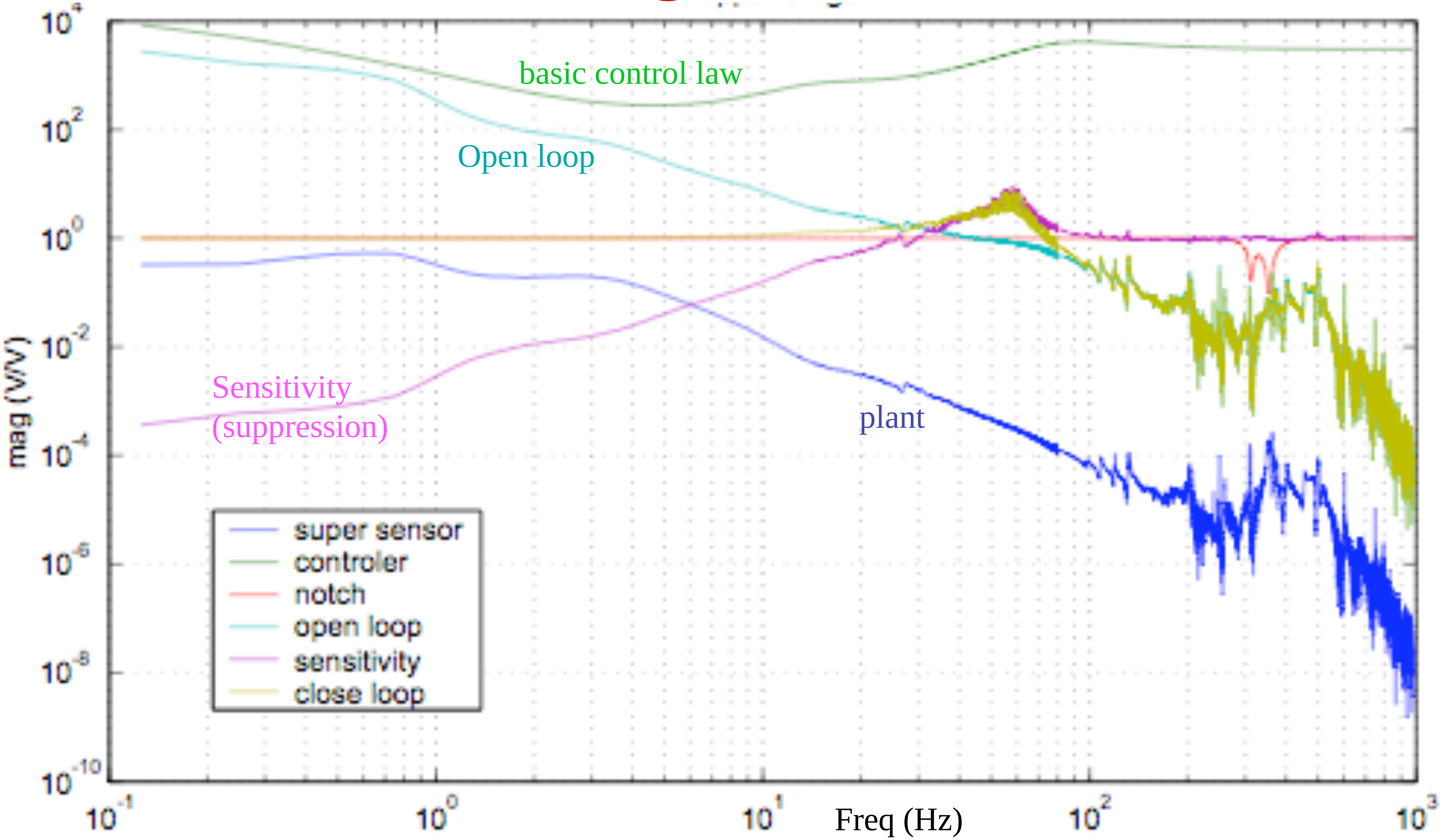
2. Create "super-sensor" in the "center basis"
   blending sensors: 3/DOF on stage 1, 2/DOF on stage 2.
   Start with 2 Hz blend.

3. Close the isolation loops for 2-stage internal system.
   Stage 1 tip & tilt (rx & ry)
   Stage 1 x, y, z, & rz.
   Stage 2 tip & tilt,
   Stage 2 x, y, z, & rz.

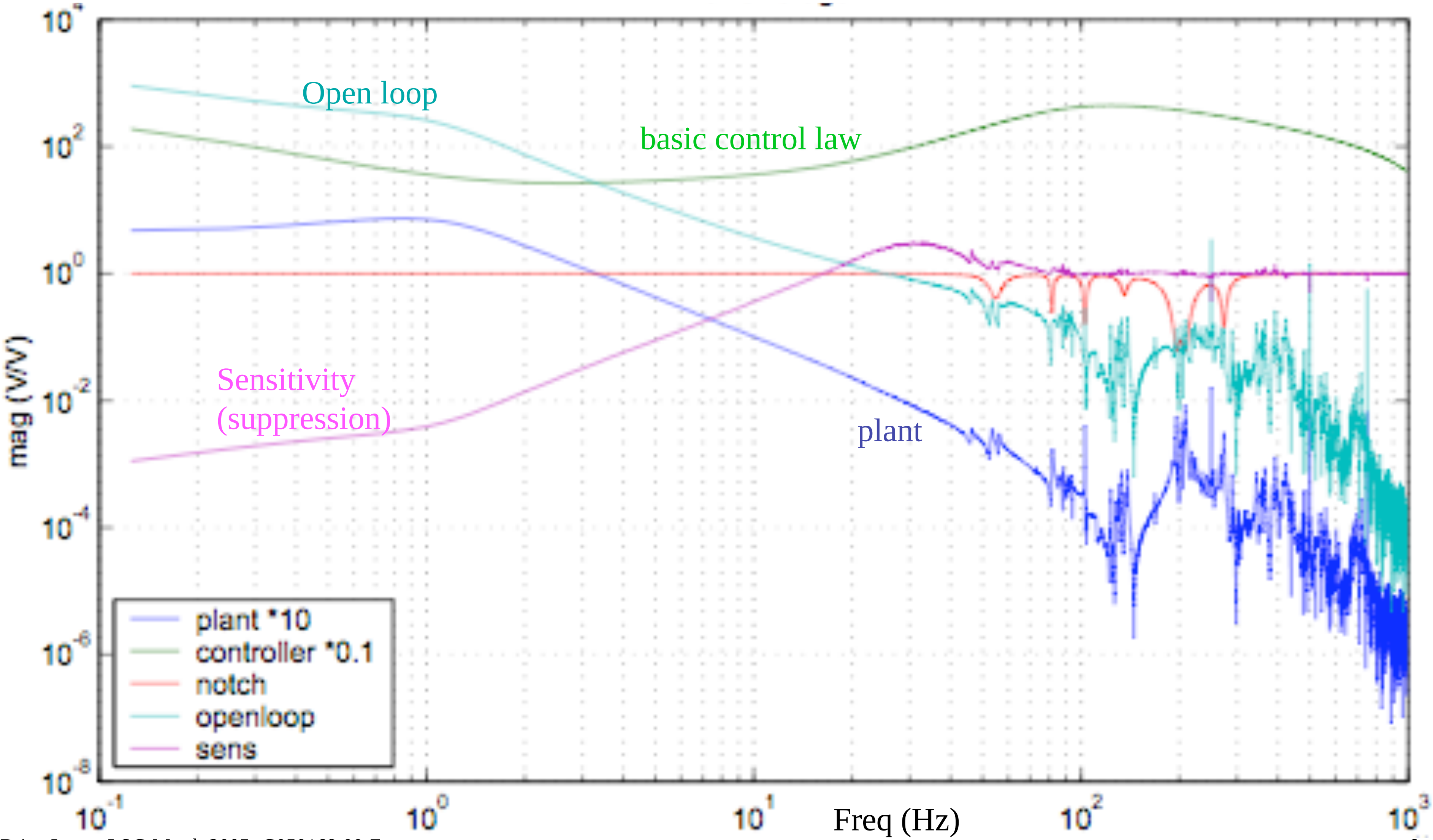
4. Generate & implement "displacement-sensor orientation correction" matrix for stage 1.

5. Lower the blend frequencies to get 1 Hz performance.

Example Control Loops
Stage 1, X



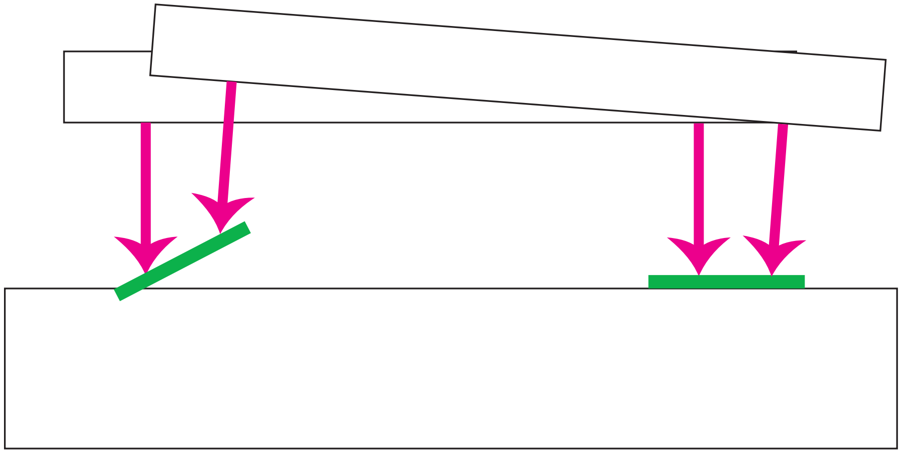
Example Control Loops
Stage 2, X



Displacement-sensor Orientation Correction

Problem: Tilt-horizontal coupling

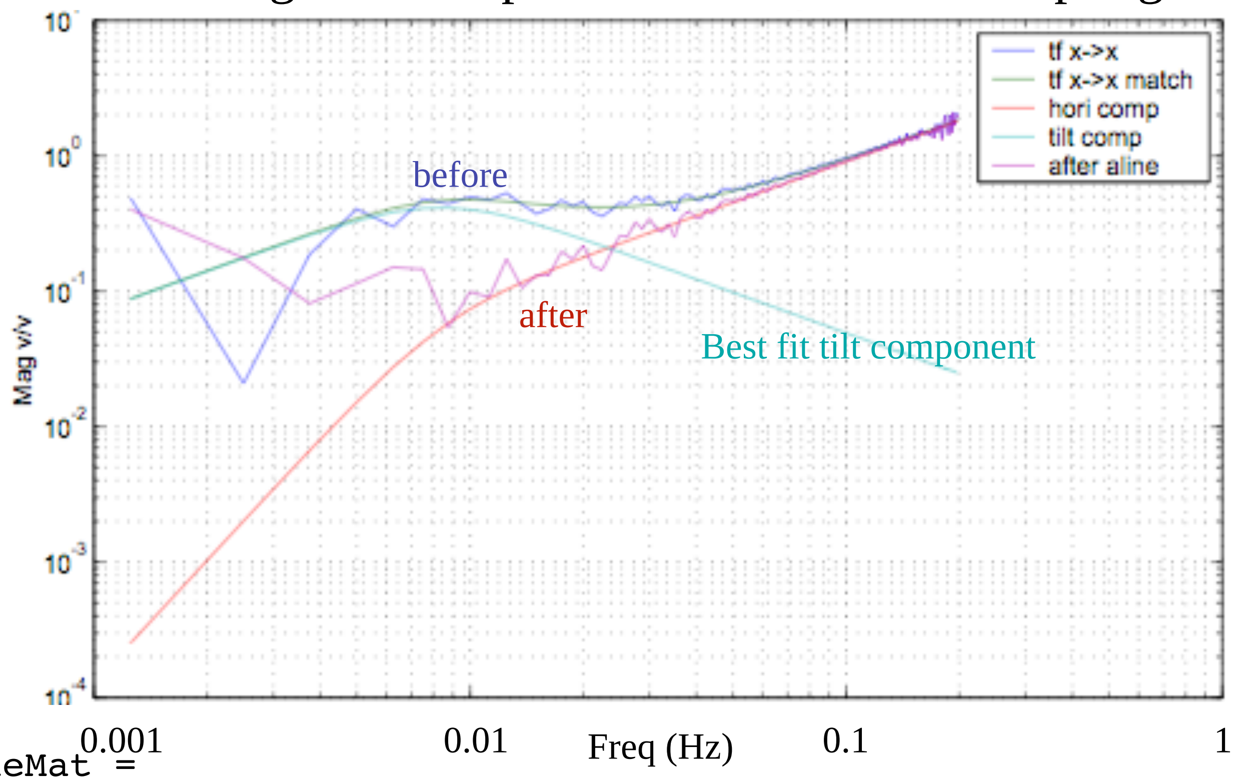
Non-parallel reference surfaces can convert translation into tilt.



Drive system in translation
Measure tilt with horizontal seismometer
Calculate the ratio of translation-to-tilt coupling
Modify code: when you command a translation, also command an opposite tilt

Benefit of Displacement-sensor orientation correction

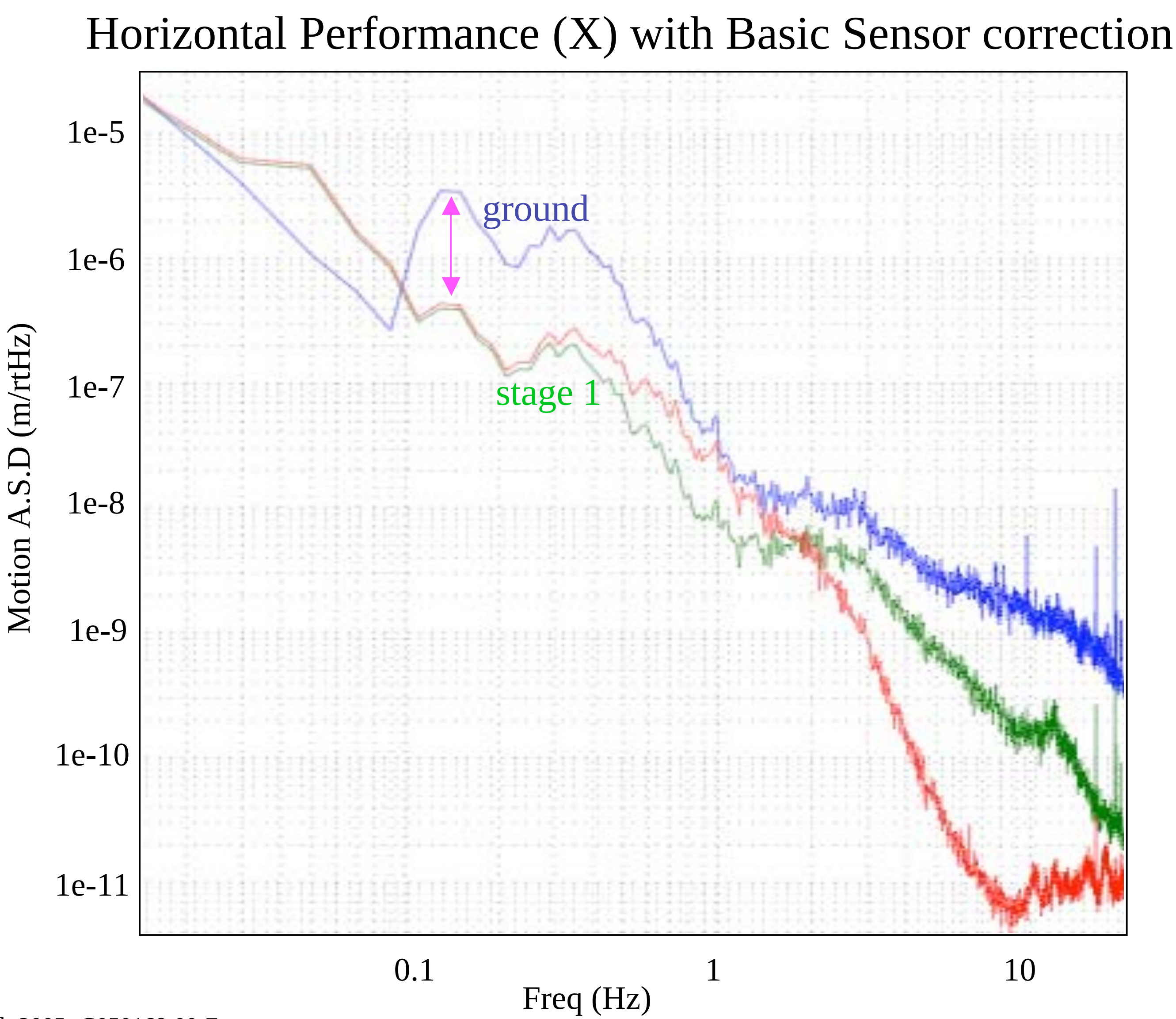
Alignment Improvement for X to X coupling



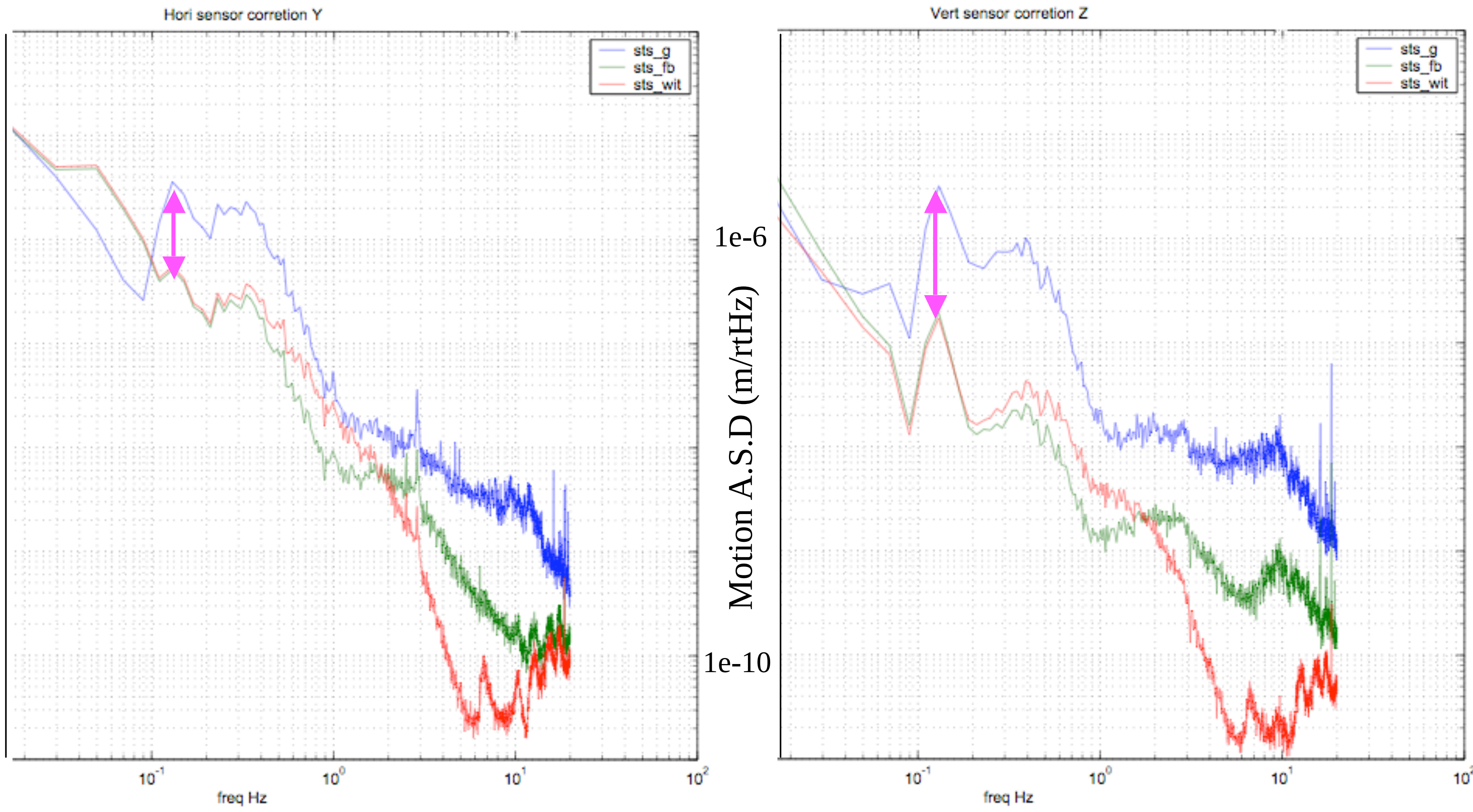
alineMat =

$$\begin{bmatrix} x \\ y \\ z \\ rx \\ ry \\ rz \end{bmatrix} = \begin{bmatrix} 1.0000 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1.0000 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1.0000 & 0 & 0 & 0 \\ 0 & -0.0006 & -0.0116 & 1.0000 & 0 & 0 \\ 0.0022 & 0 & 0.0147 & 0 & 1.0000 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.0000 \end{bmatrix} * \begin{bmatrix} x \\ y \\ z \\ rx \\ ry \\ rz \end{bmatrix}$$

Sensor Correction Still Works



Sensor correction in Y and Z



Lower the blend frequencies

Goal: Factor of 100 isolation at 1 Hz without using sensor correction

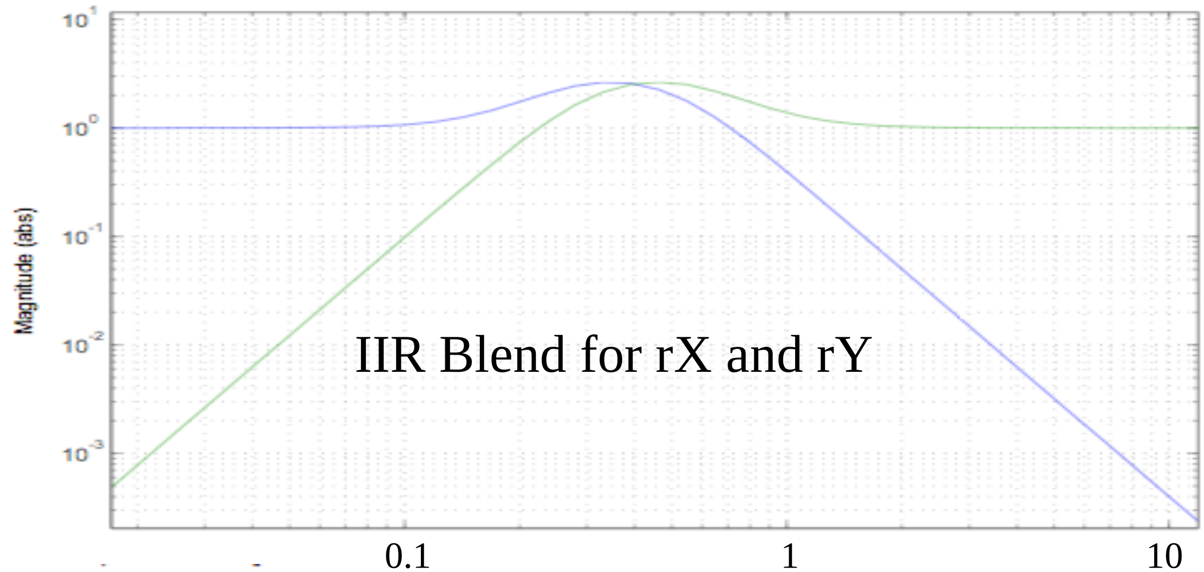
In our current implementation,
First, normalize all sensors to match dynamics of displacement sensor
Then, design blend filters which add to 1
Benefits:

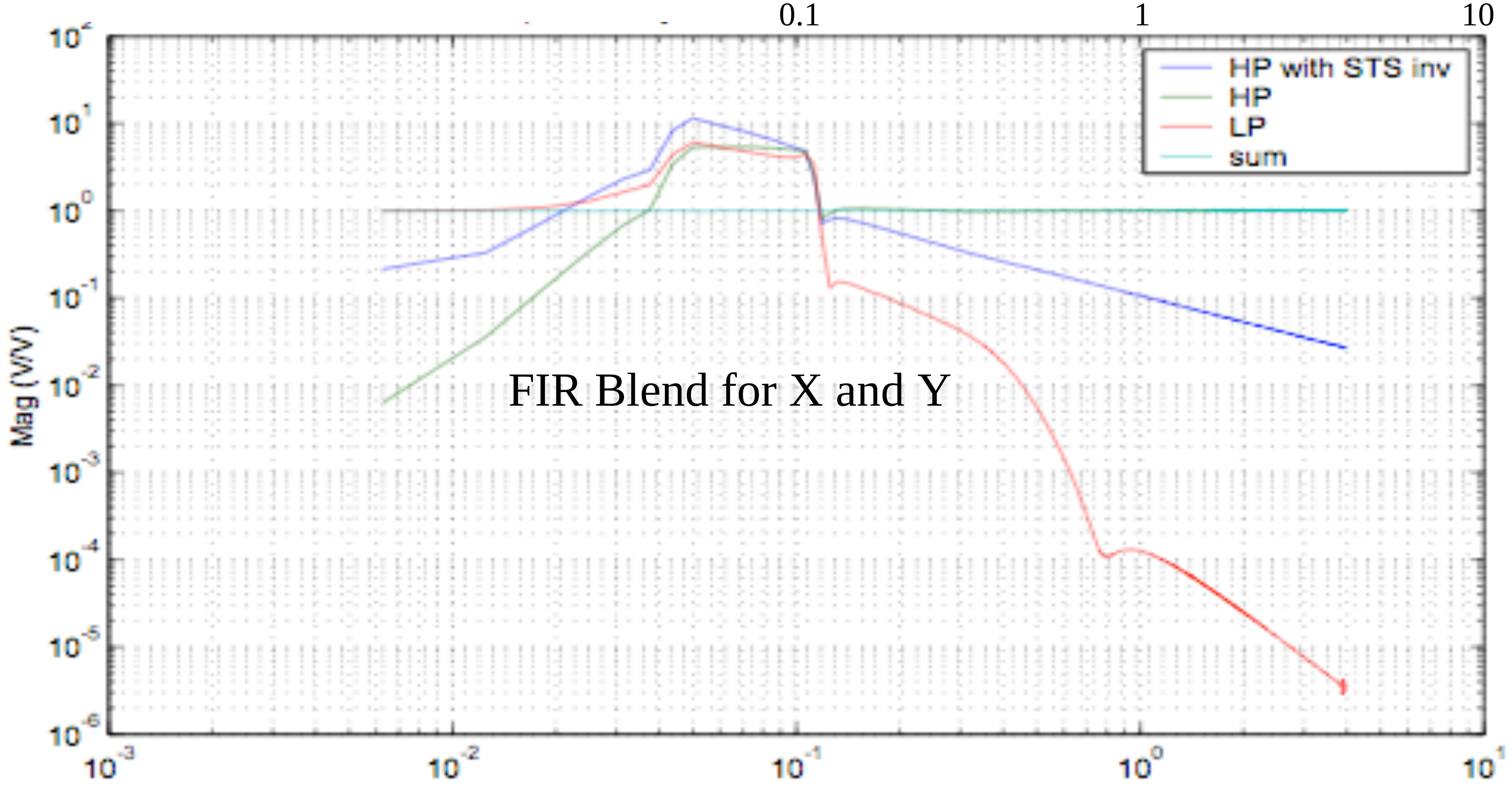
- Simplifies design of the blending filters.
- Moving blend frequency doesn't change the control loop.
- Total change of filters doesn't change the control loop.

Drawbacks:

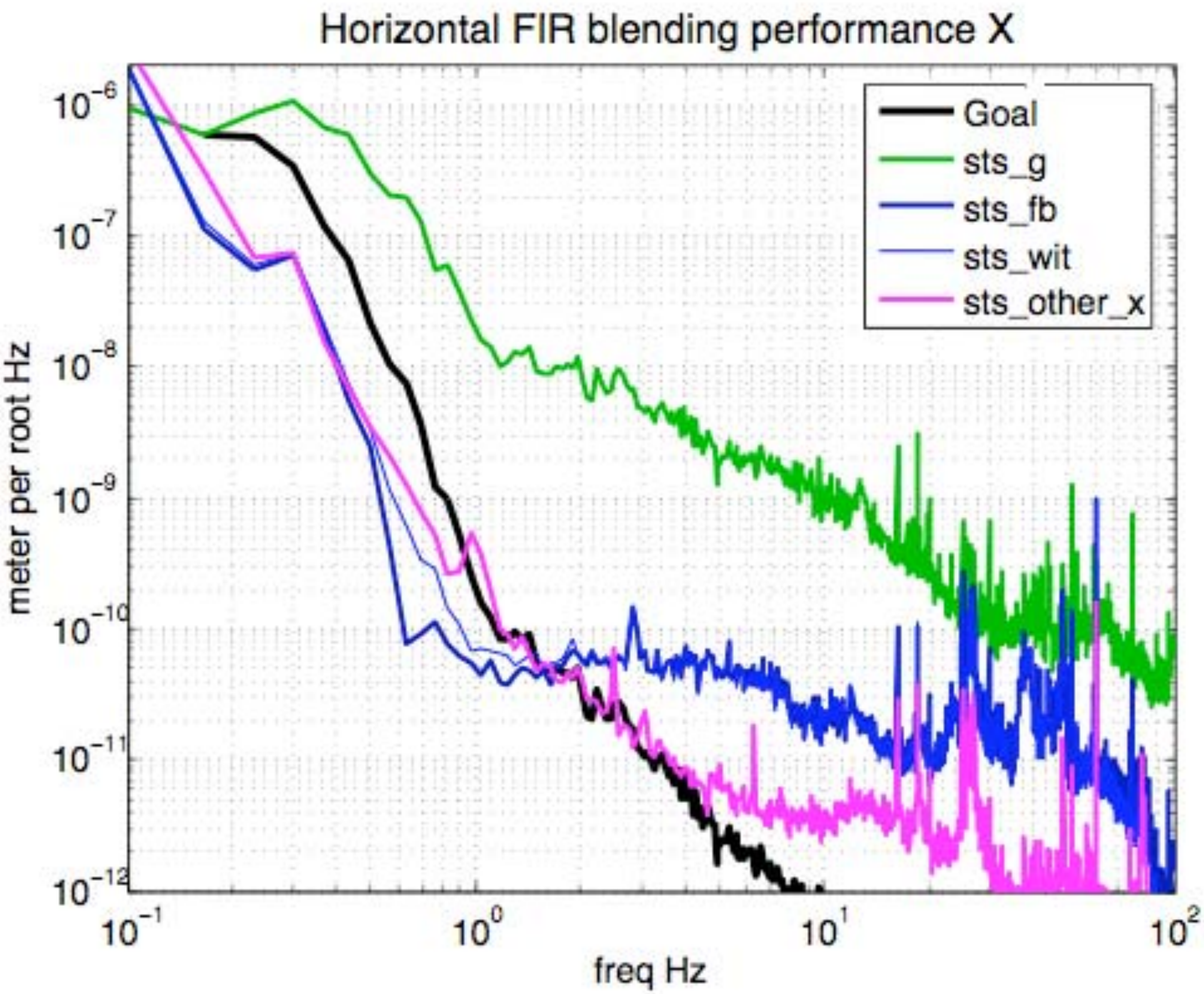
- Inverting inertial sensors gives many unwanted zero-frequency poles.
- Have to develop techniques to cancel these effectively.

Stage 1 Blending

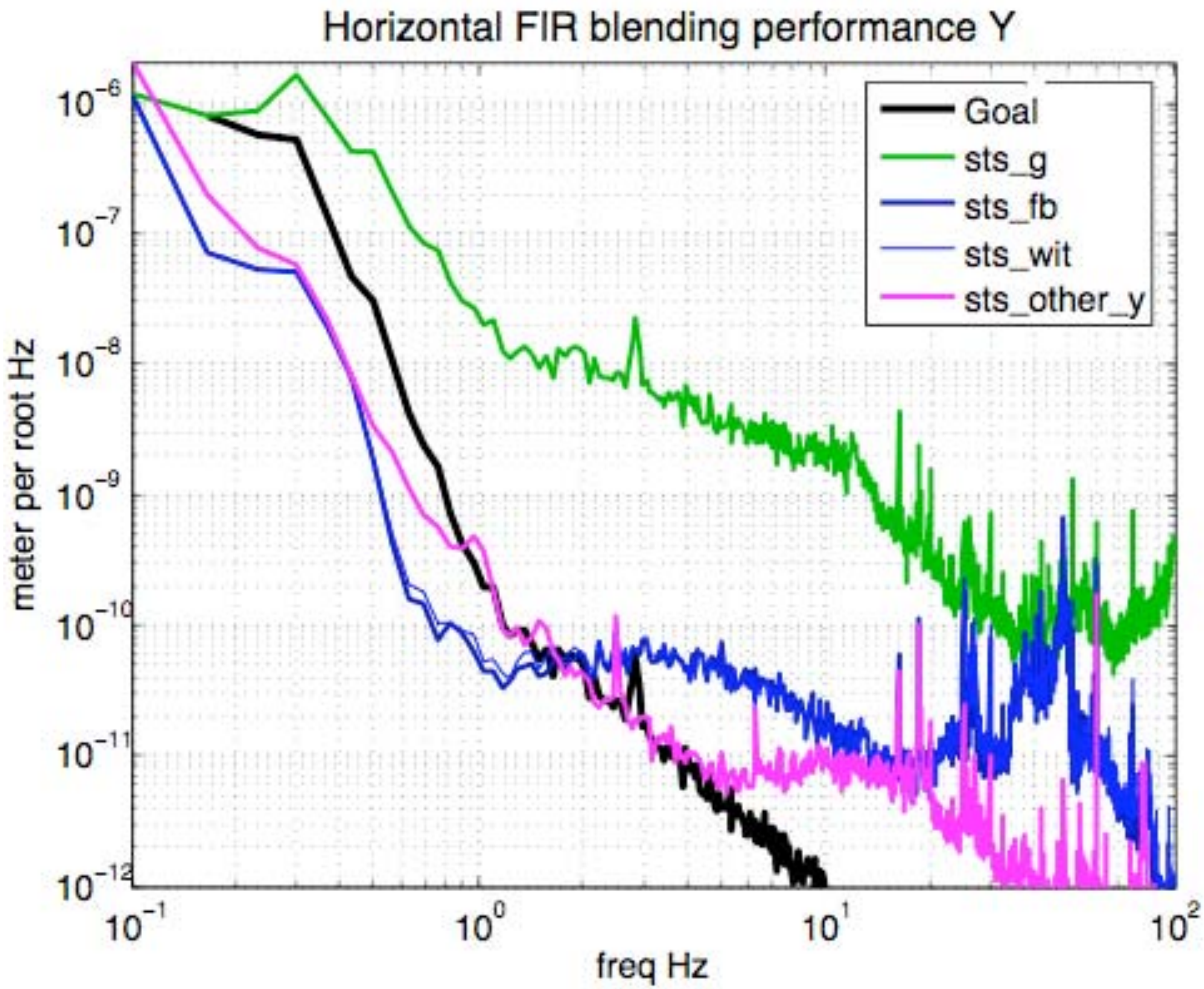




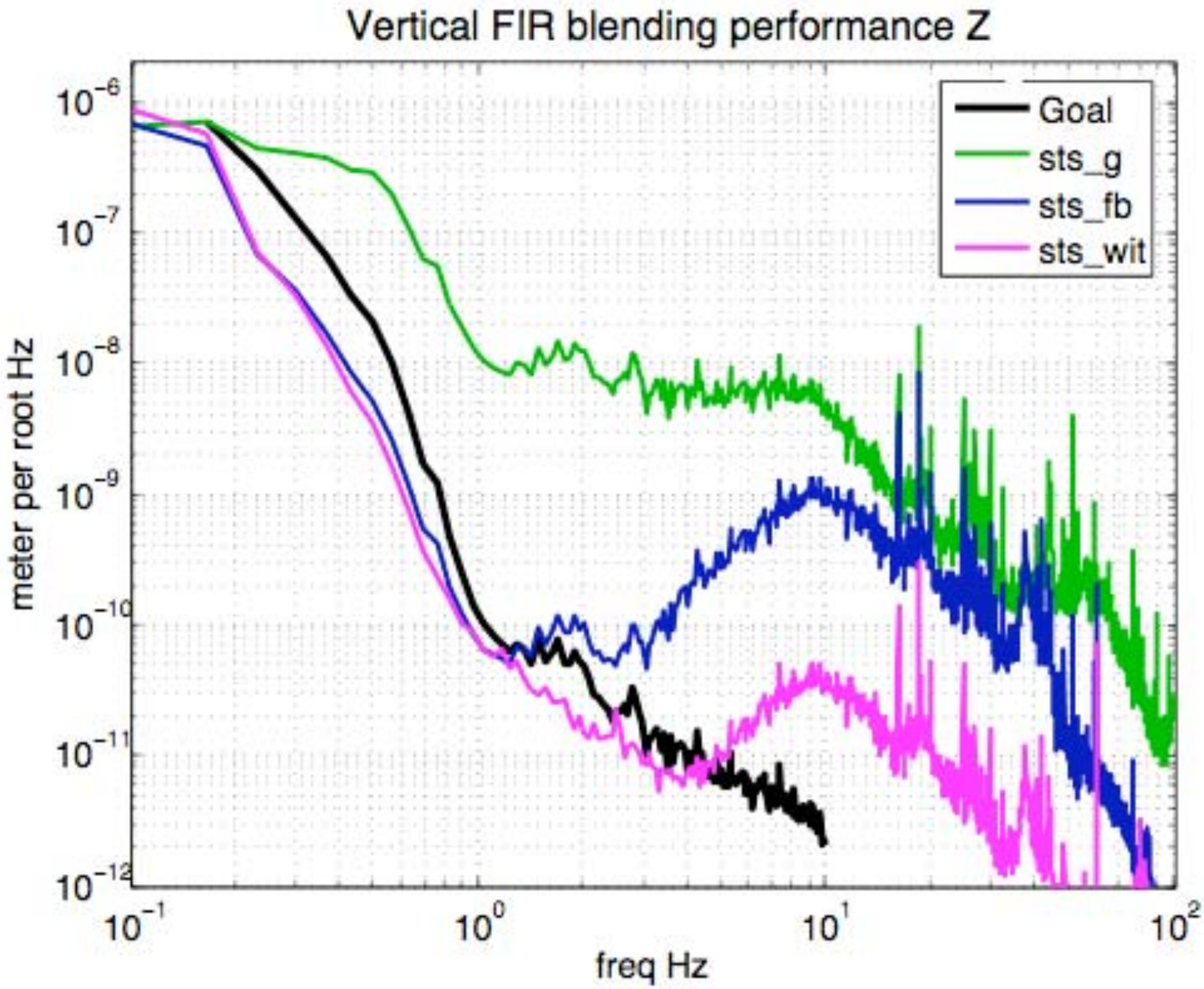
Performance in X



Performance in Y



Performance in Z



Next on the list…

- Study the sensor noise.

  The quiet platform allows us to (finally) investigate the noise performance of the sensors.

- Study excess drive.

  Something other than stage 1 motion is applying forces to stage 2. Magnetics? Improperly secured cables? Rana’s RF sidebands?

- Try to improve the 10 Hz performance.
- Study frame interactions.

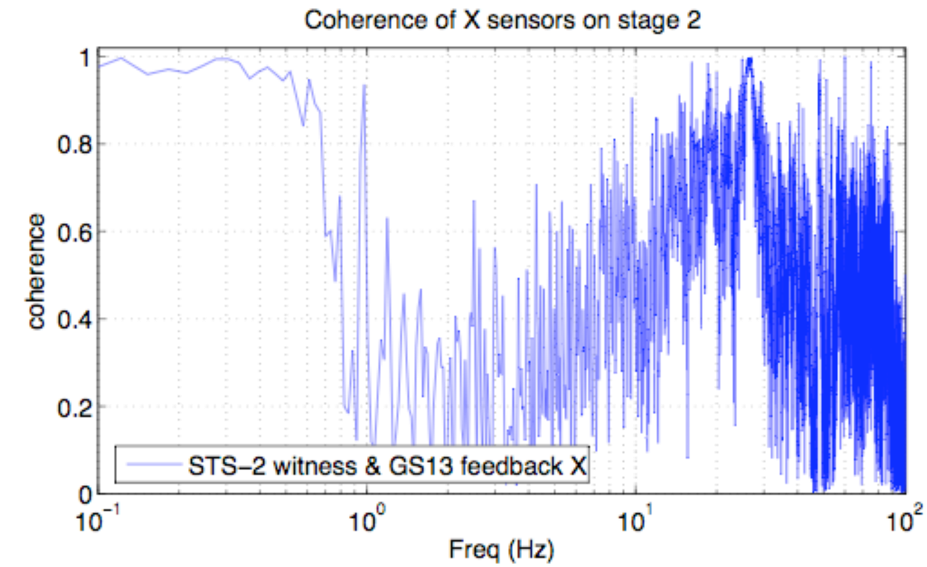
  See presentations by Janeen and Calum.

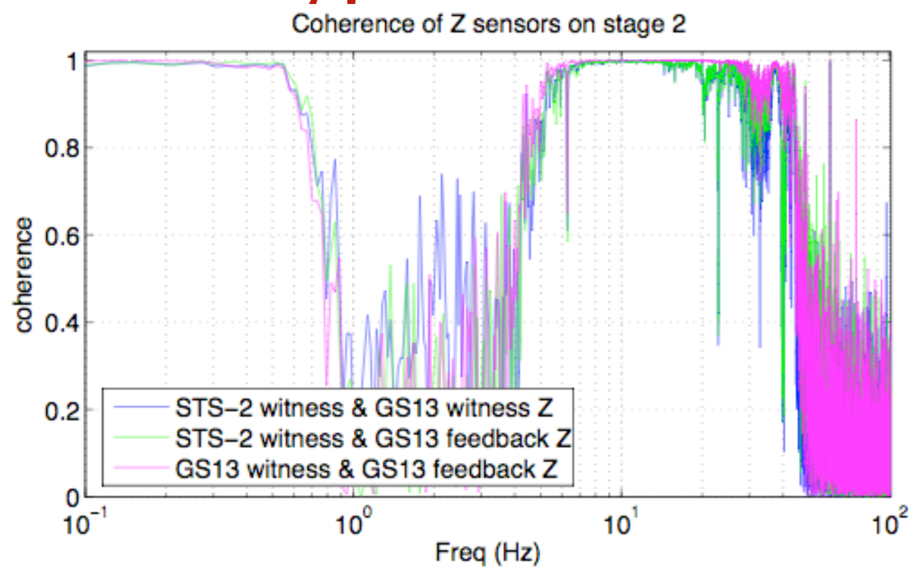
Conclusions

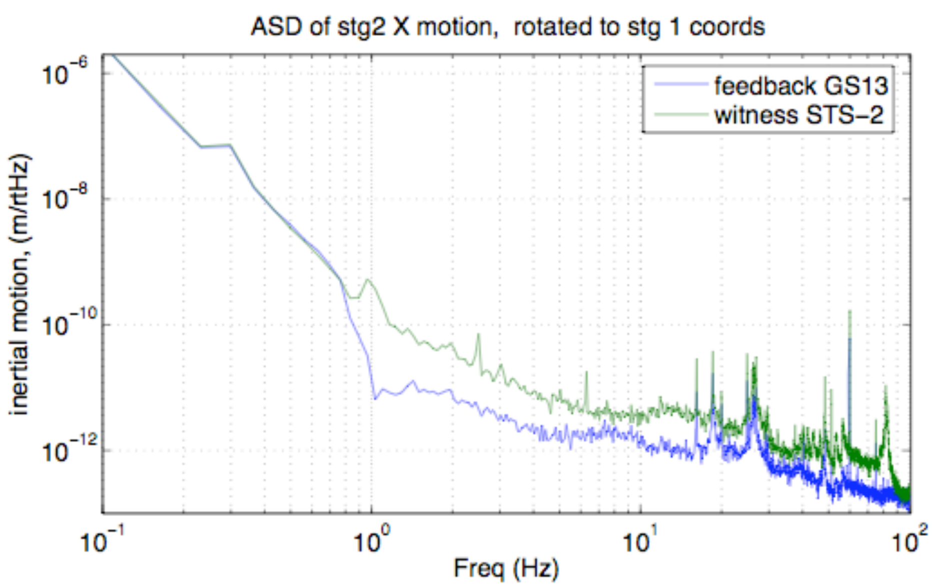
1. We can achieve an isolation factor of 100 at 1 Hz using only feedback. This is experimental validation of the isolation technique planned for Advanced LIGO.

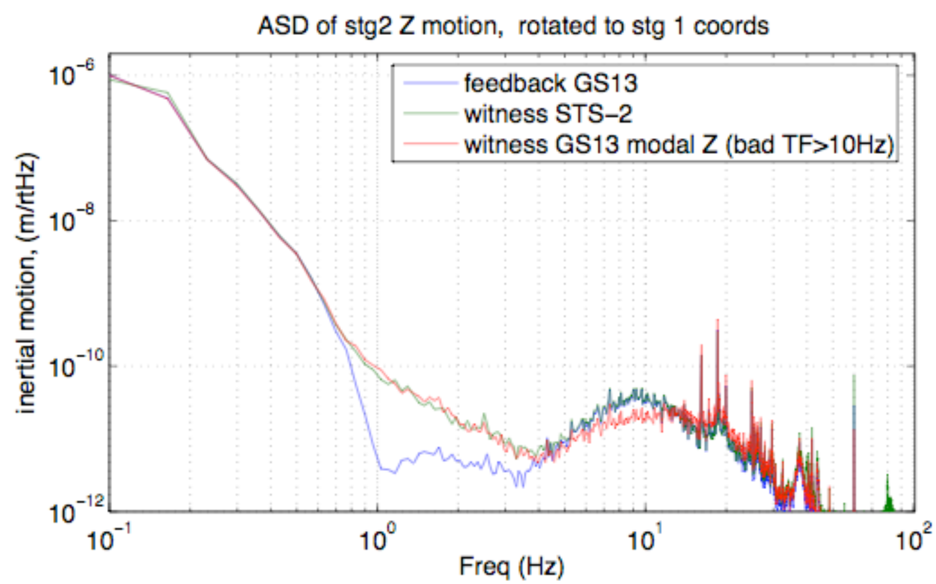
2. But, we still have work to do…

Sensor Noise on Stage 2

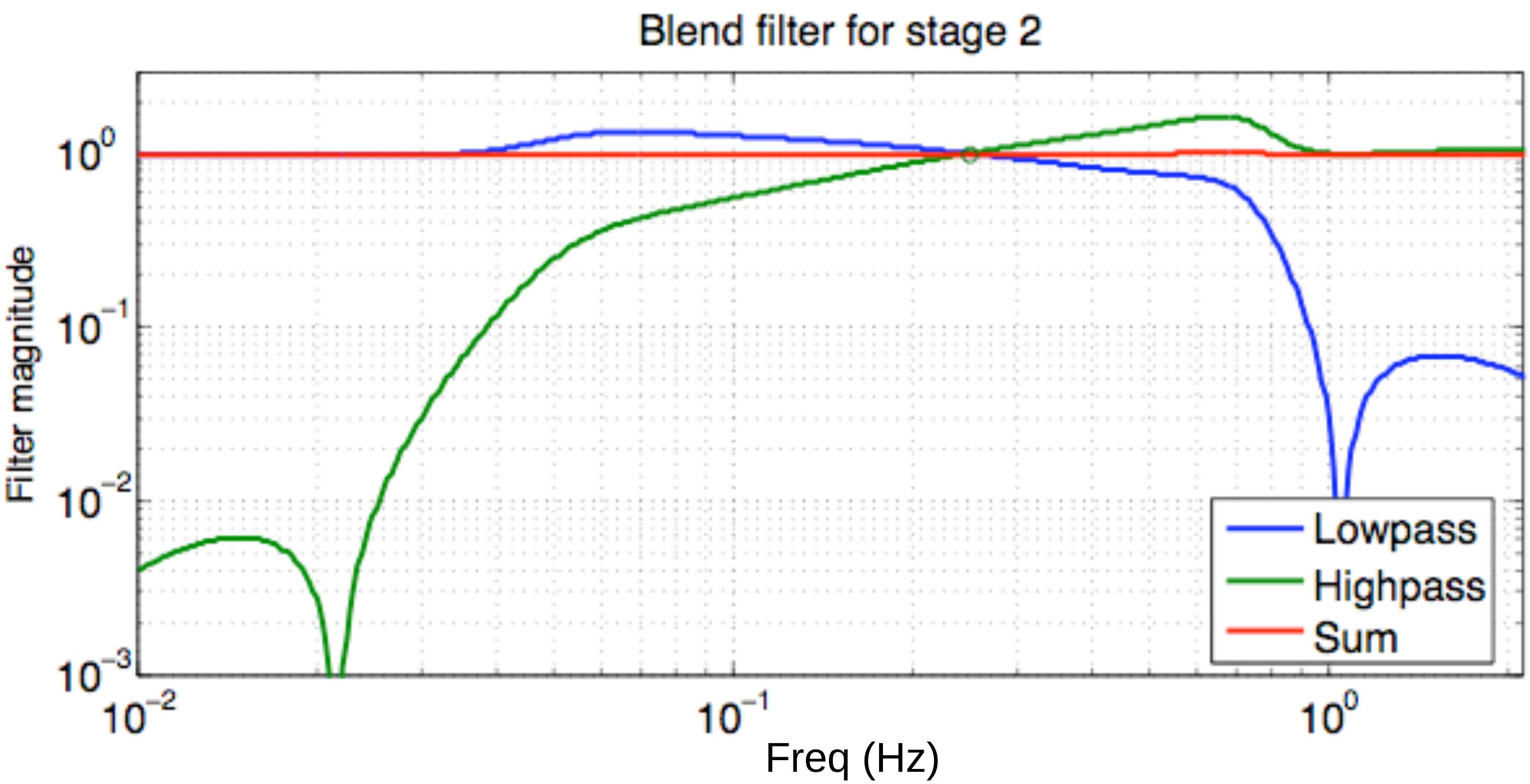




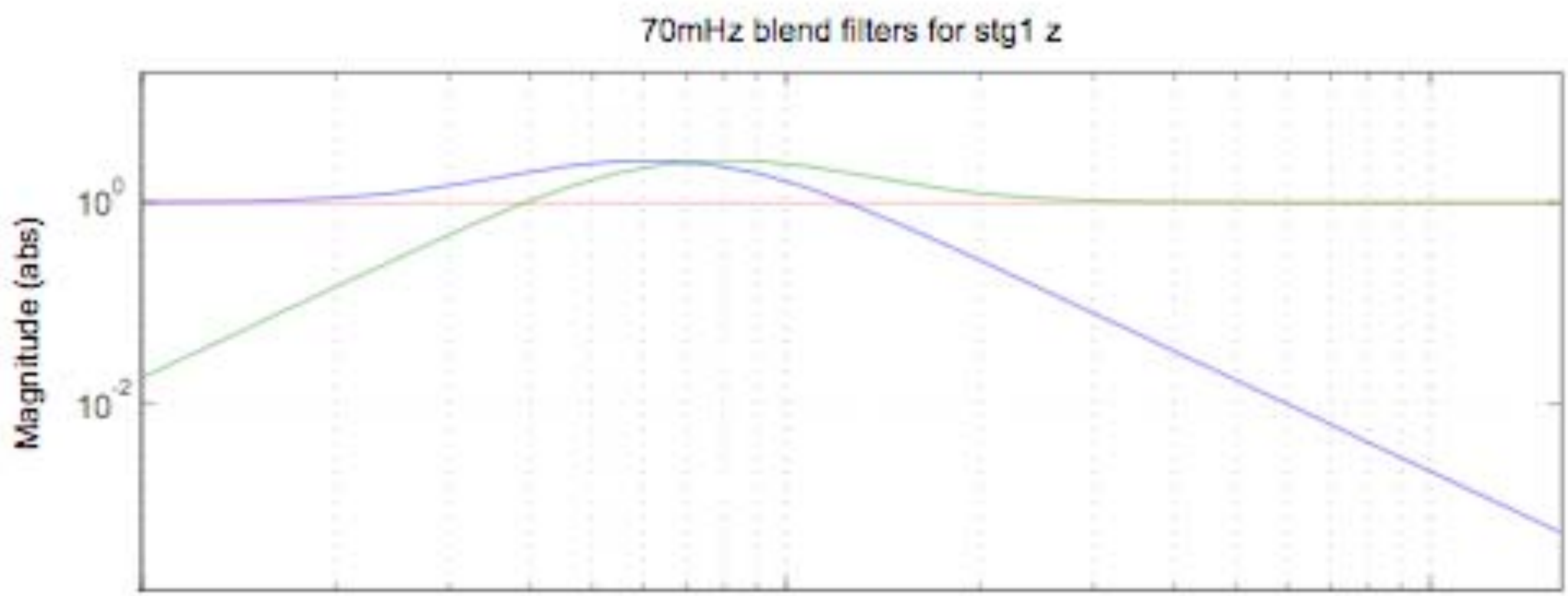




Blend filter for stage 2



Blend for stage 1 Z



Possible Blend Filter for Stage 1