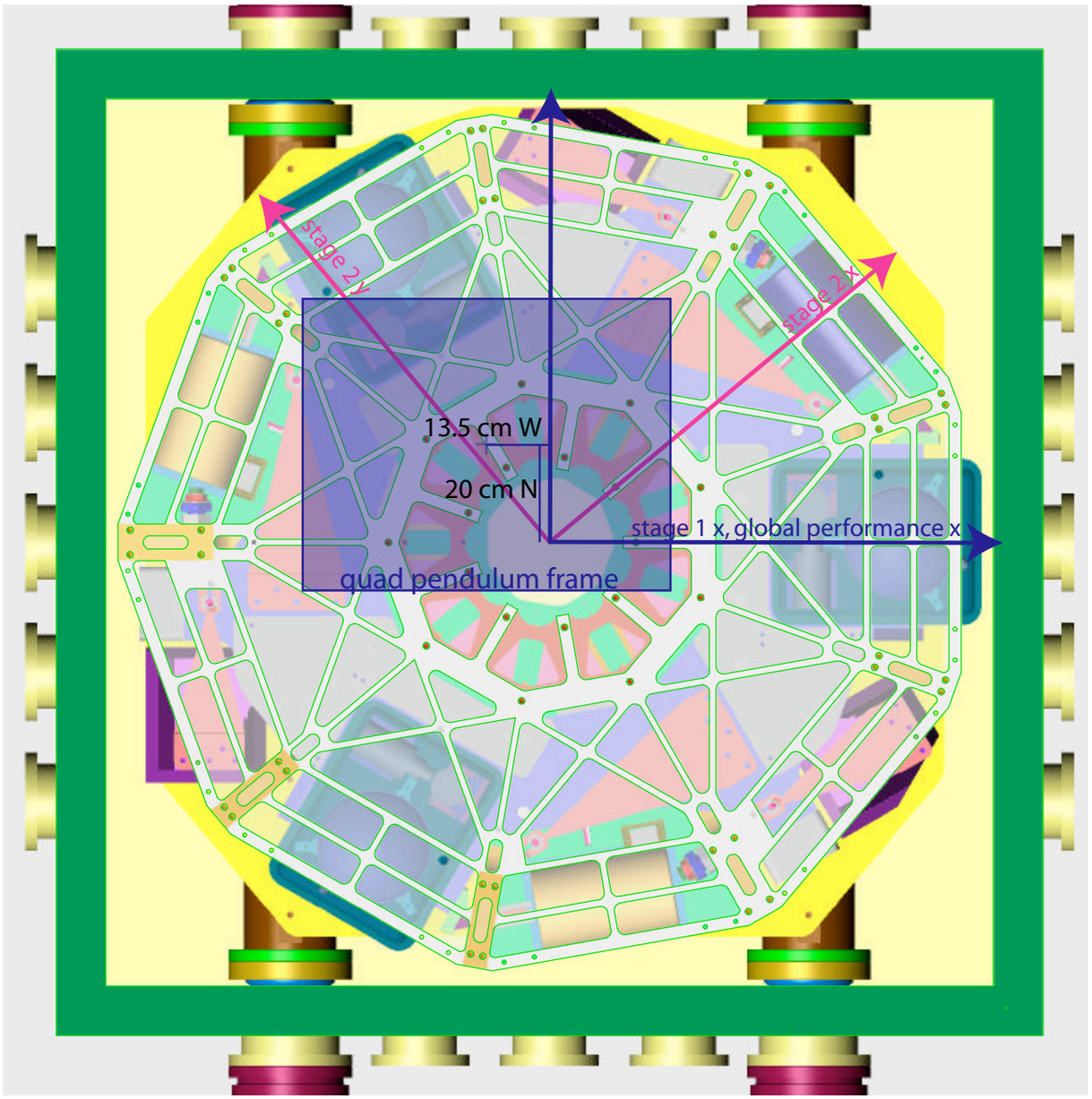
Results of the Frame Interaction Study at the ETF

Brian Lantz, Jan. 12, 2006

with special thanks to Calum, Janeen, and Norna

Installation

- Installed 12/16/05
- Upside down



top view of frame placement on table

Installation Notes

- Frame center offset from table center
  20 cm N (beam direction), 13.5 cm W (transverse)
  (similar to AdLIGO, fits reasonably well on the table).
- Installed on "Stage 2" of seismic system (optics table).
- Frame replaced weights on optics table so total load and balance unchanged (but moment increased).
- Used 35 dogs.
- Tank top removed, lots of acoustic disturbance.

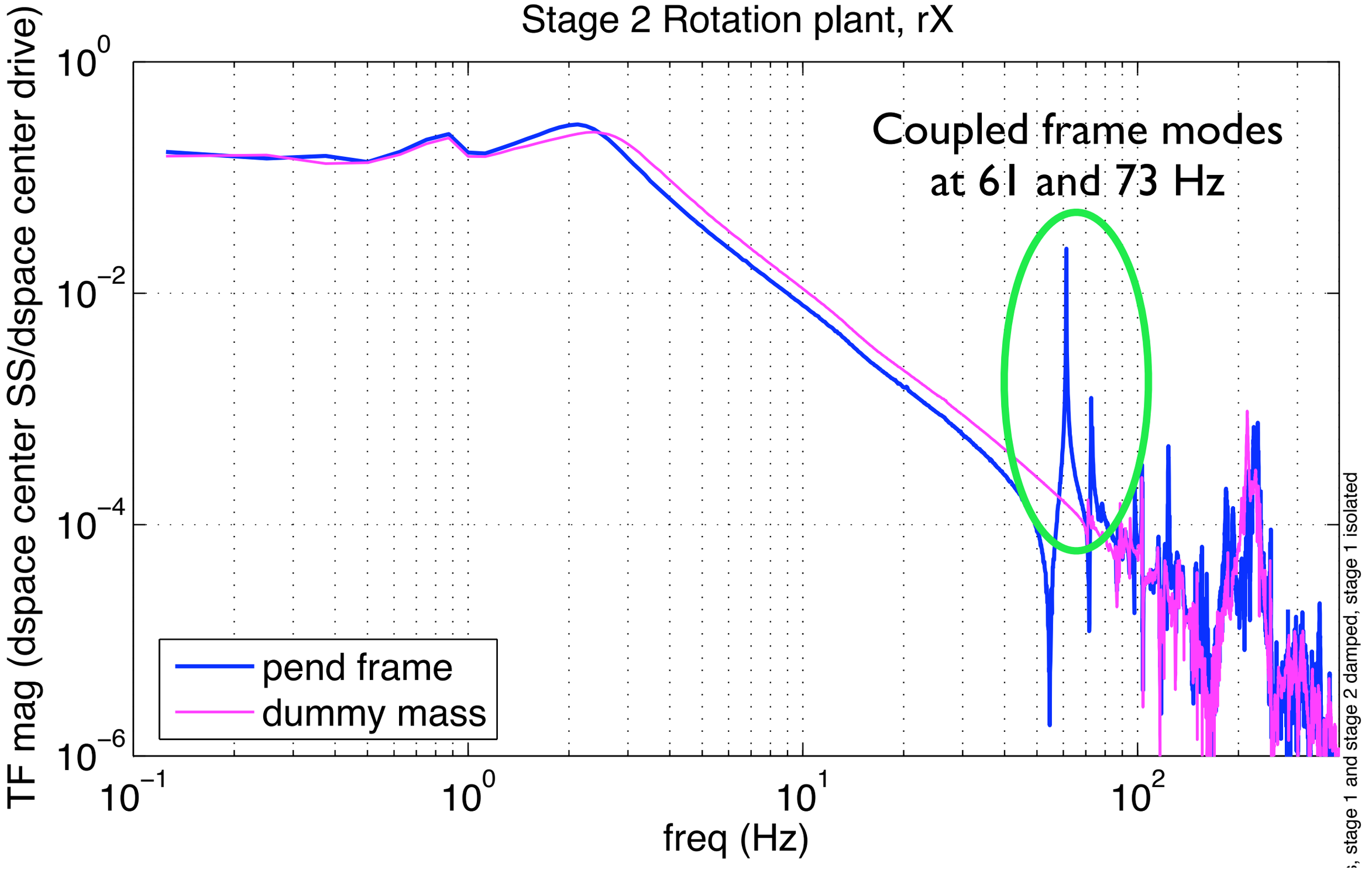
Tests

- Goal: Try to understand the impact of the frame vibrations on the system performance.
- But: Testing in air makes performance measures difficult.
- So: Predict performance by:
  - Measuring mechanical transfer function of stage, and
  - Multiplying by calculated suppression of the isolation loop.

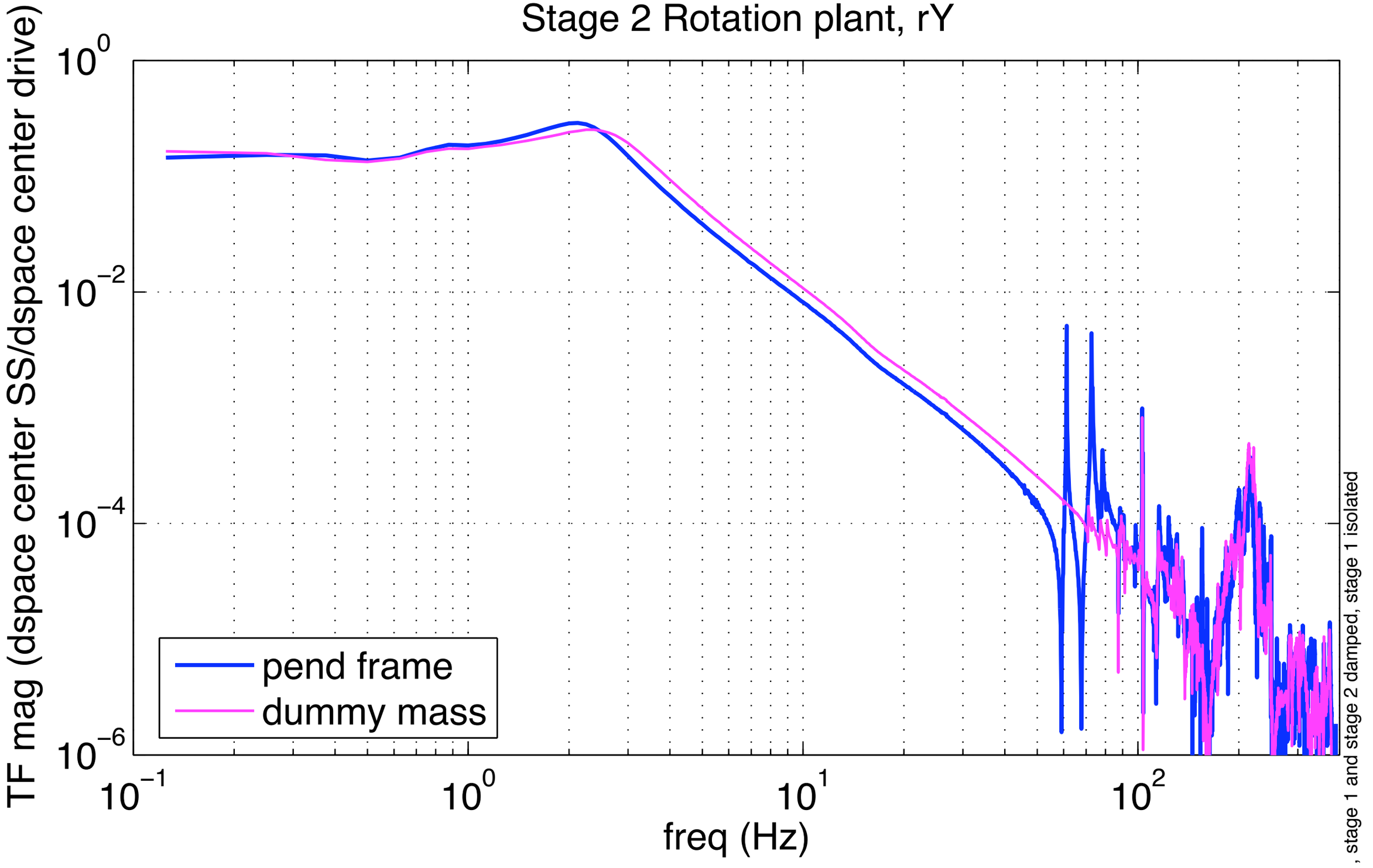
- We see that:
  - Mechanical transfer function is worse,
  - Control loop performance is worse,
  - Some active damping of frame modes is possible (but...)

- For tests: stage 1 damped and isolated, stage 2 damped.

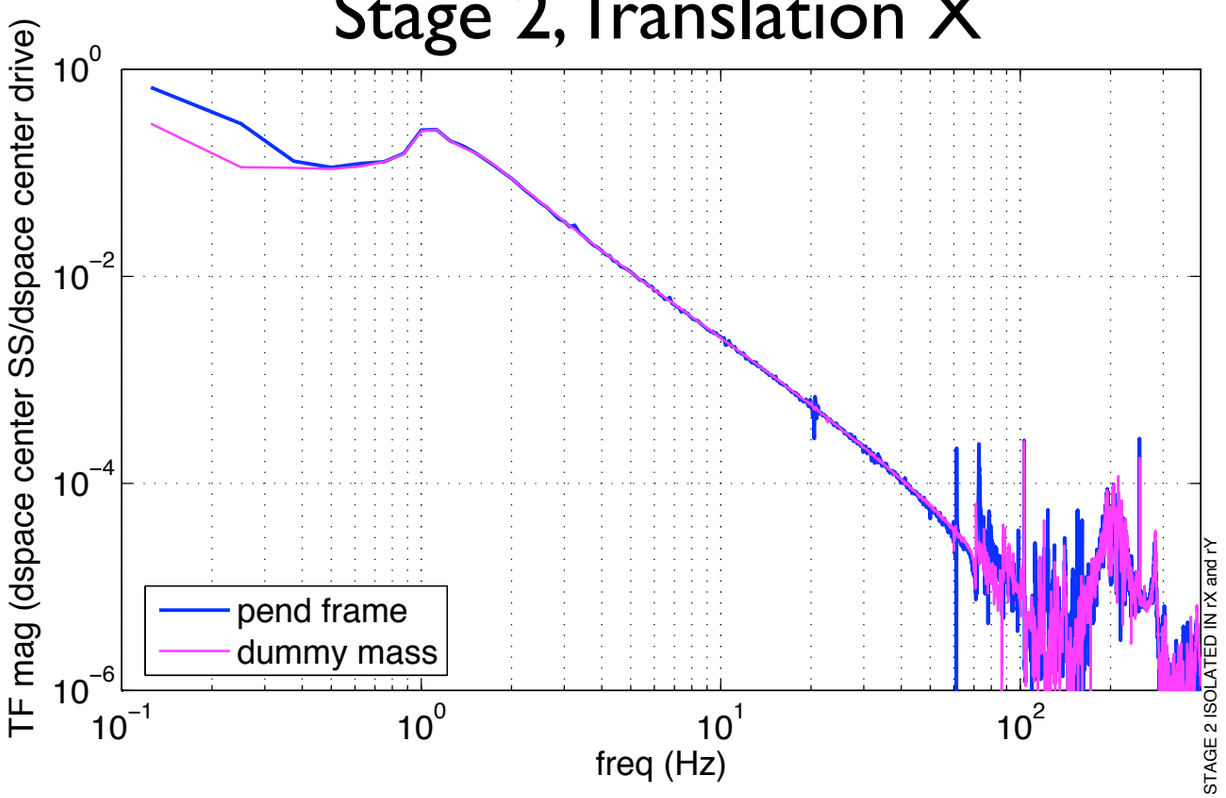
Main coupling to rX and rY

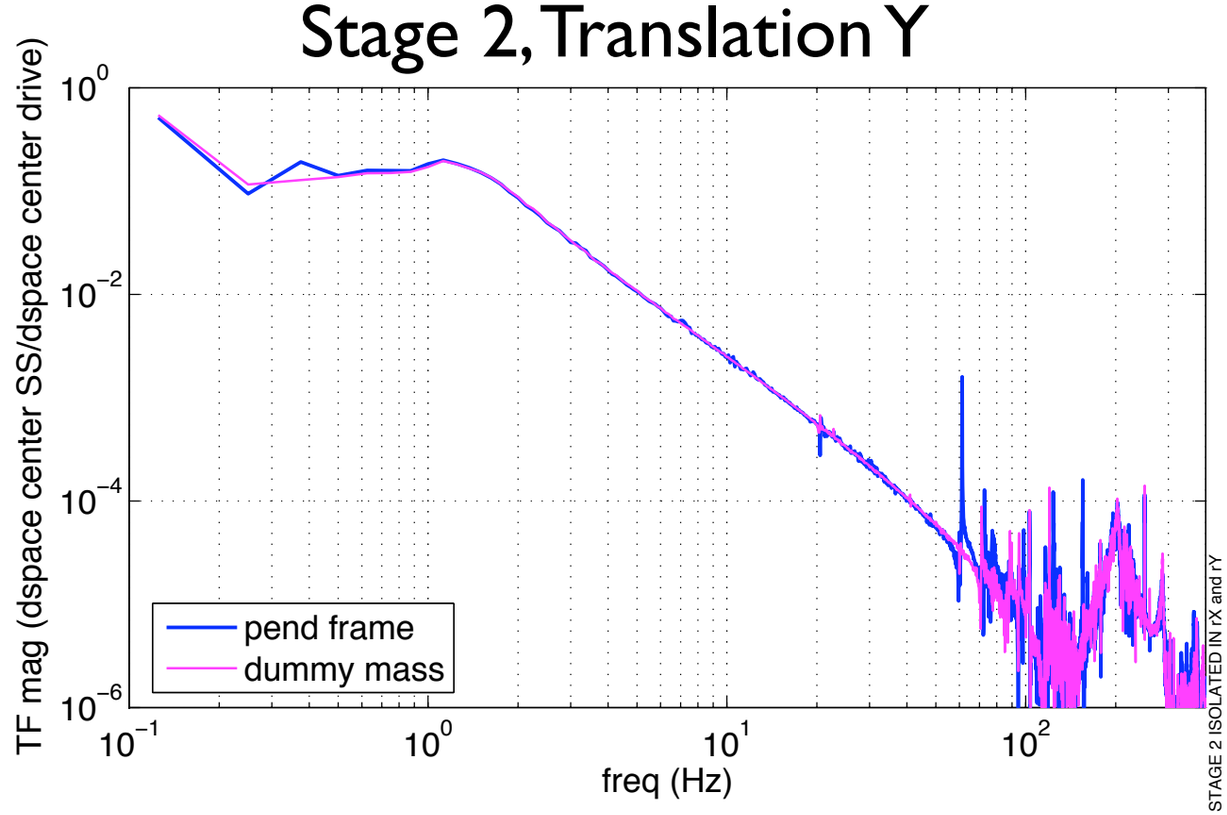


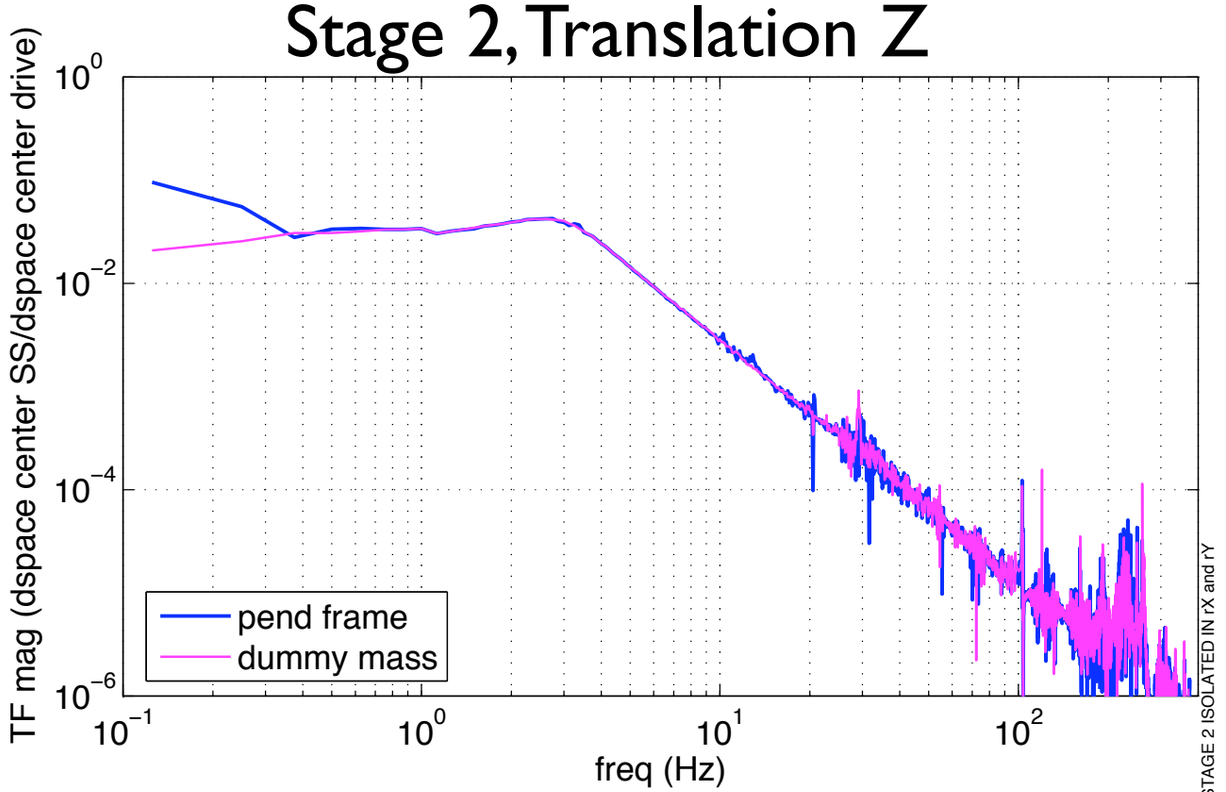
Main coupling to rX and rY

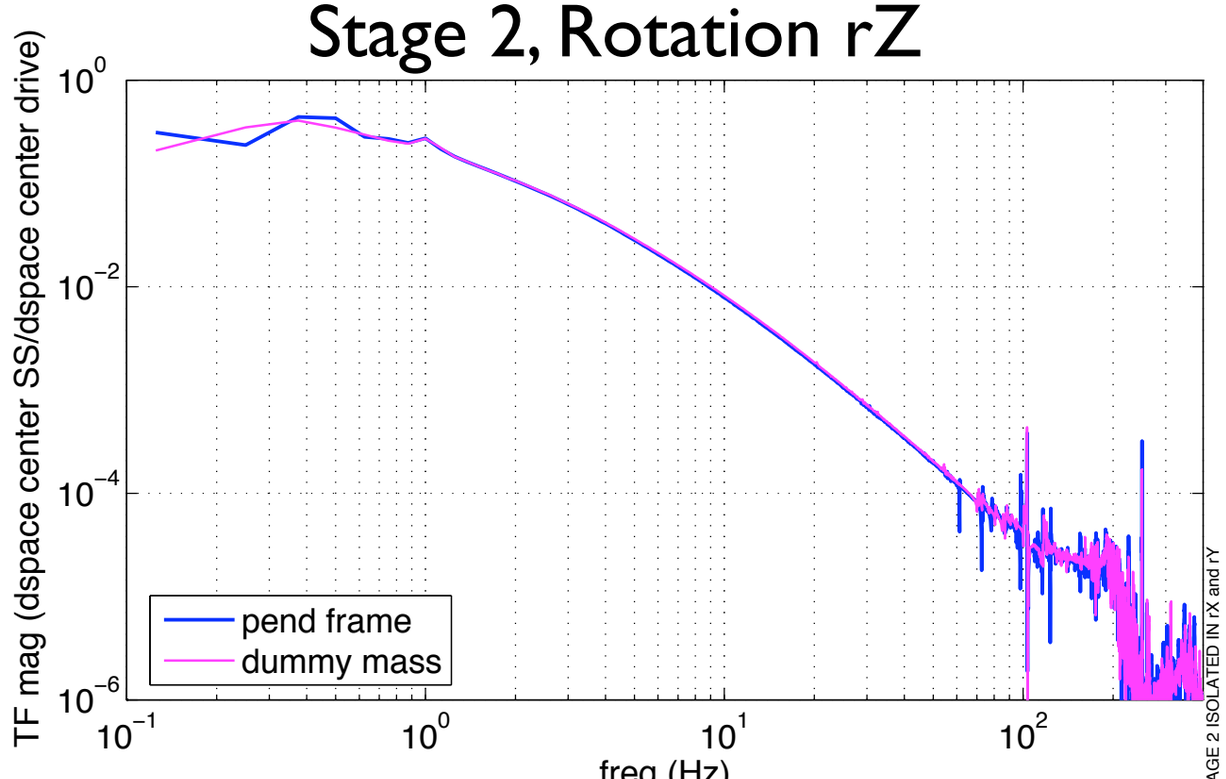


Also couples to X and Y

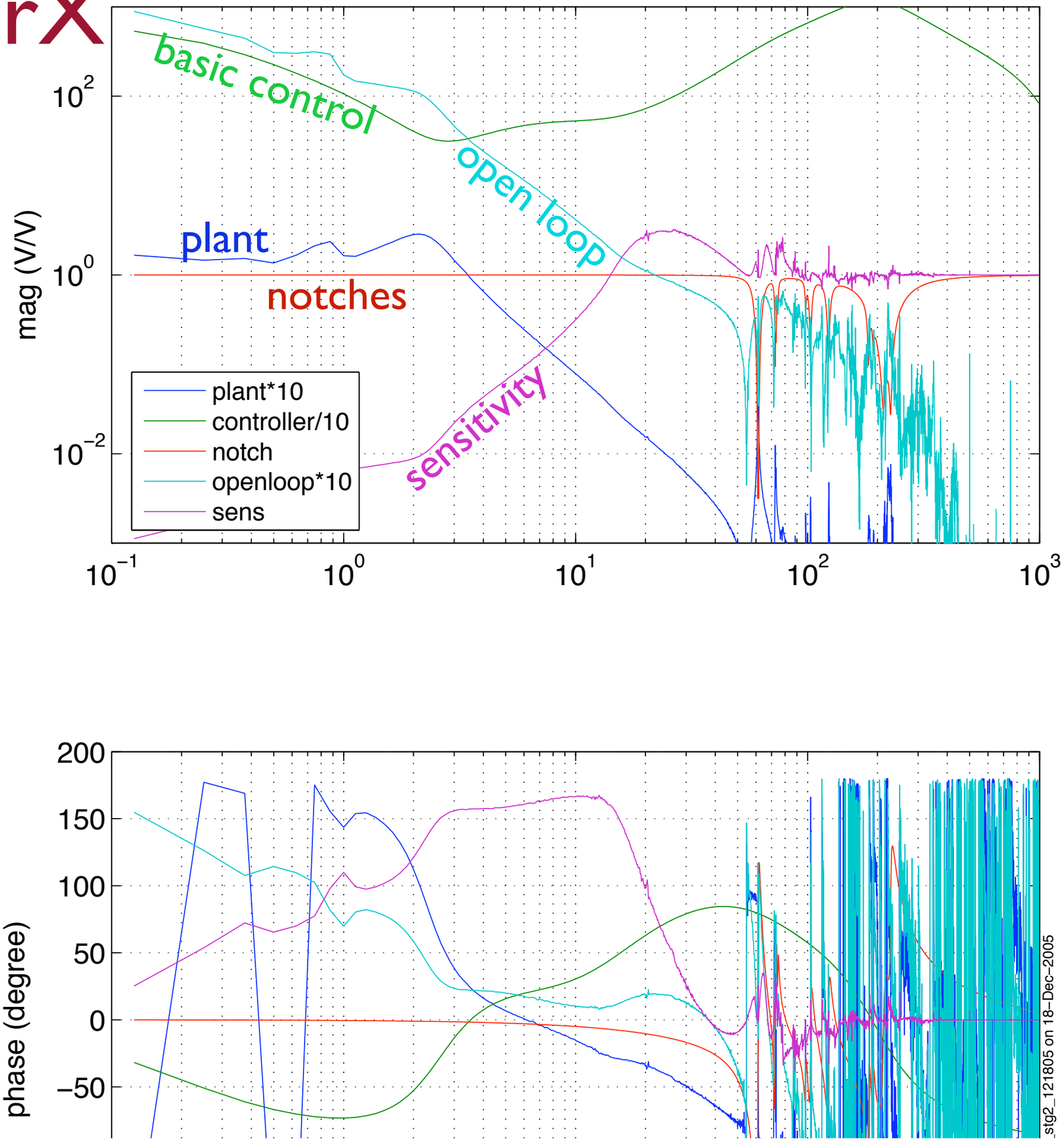








Servo for rX


ETF Stage 2, rX
basic control
open loop
plant
notches
sensitivity
mag (V/V)
plant*10
controller/10
notch
openloop*10
sens
phase (degree)
_stg2_121805 on 18–Dec–2005

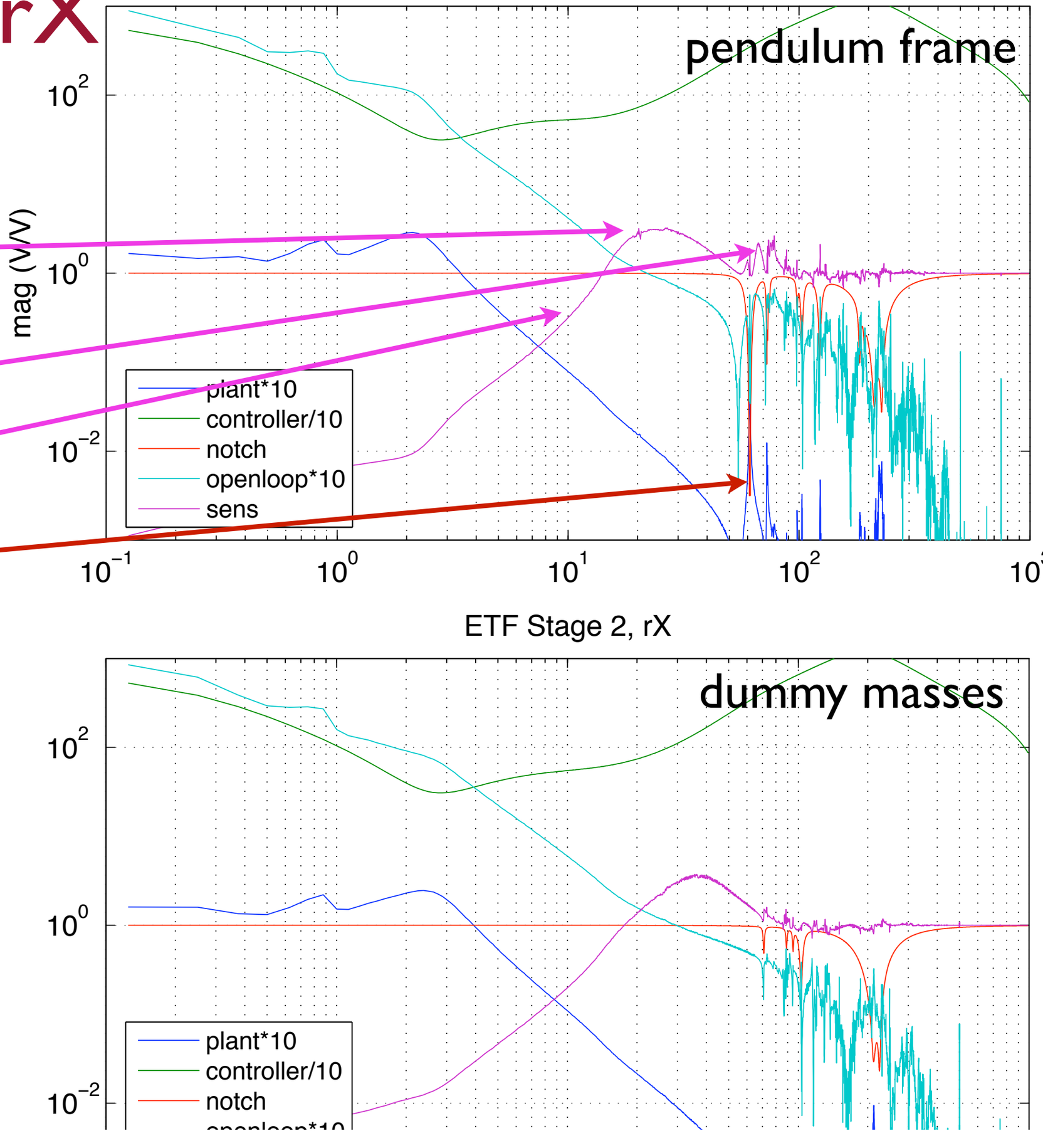
Servo for rX

<u>To notice:</u>

1. Servo amplifies above 13 Hz.
2. ‘Hair’ about 70 Hz
3. 10 Hz attenuation is modest:
4. Big notches
5. It works.

<u>Dummy mass loop is:</u>

1. Better performance.
2. More robust.
3. Easier to design.



Performance Impact of resonances

ETF Stage 2 – transmission (norm(plant) * sensitivity), rX, before and after

To predict performance:
multiply passive transmission
by the sensitivity

1. Somewhat worse between 10 - 30 Hz

2. Much worse
at peaks

with pendulum frame

with dummy masses (scaled)

Note:
I have equalized passive transmission
at 10 Hz by dividing dummy mass by 1.38.

dummy masses
pendulum frame

mag (V/V)

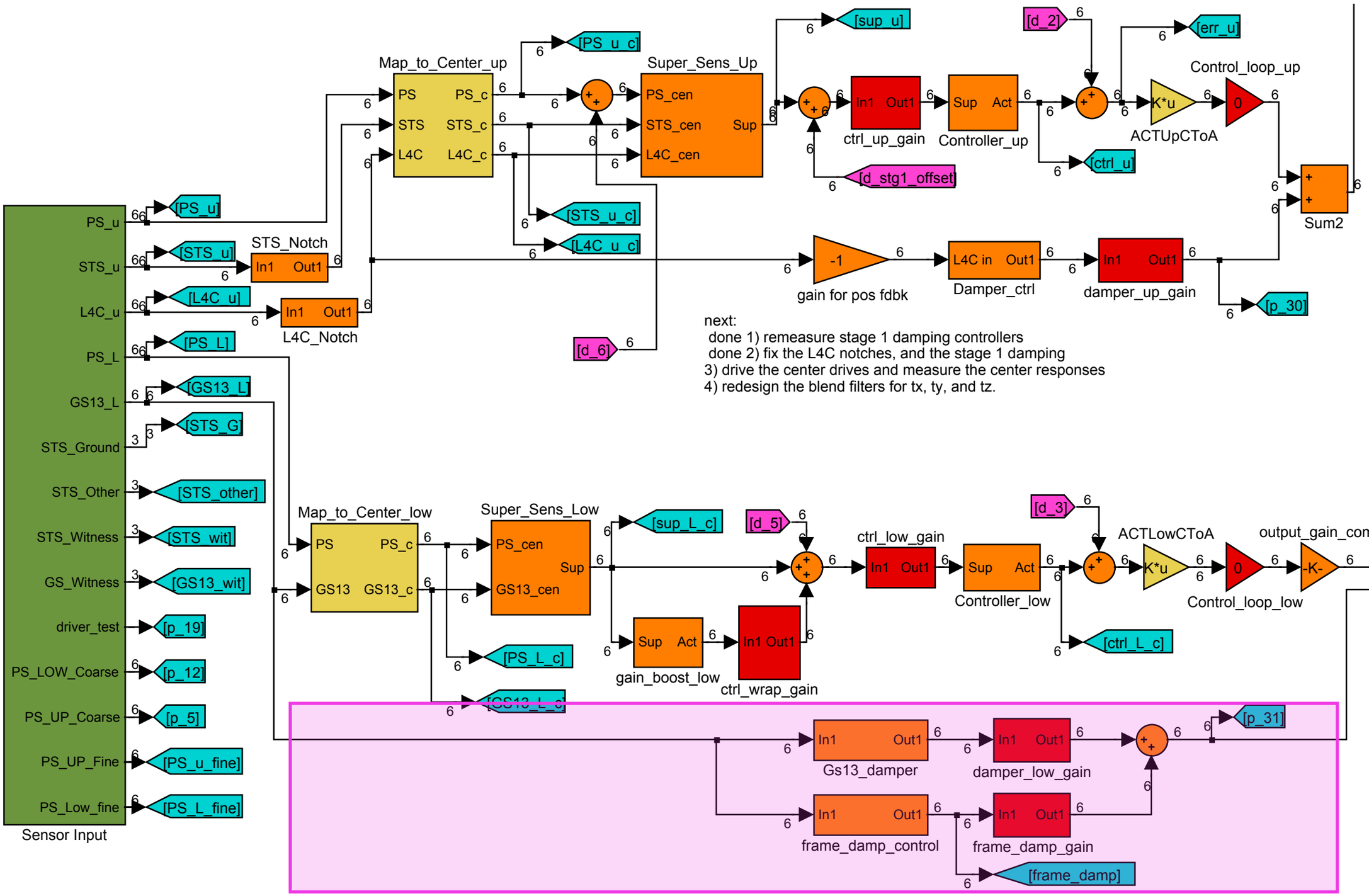
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{1}
10^{2}

created by design_txty_stg2_121805 on 18-Dec-2005

Damping the frame

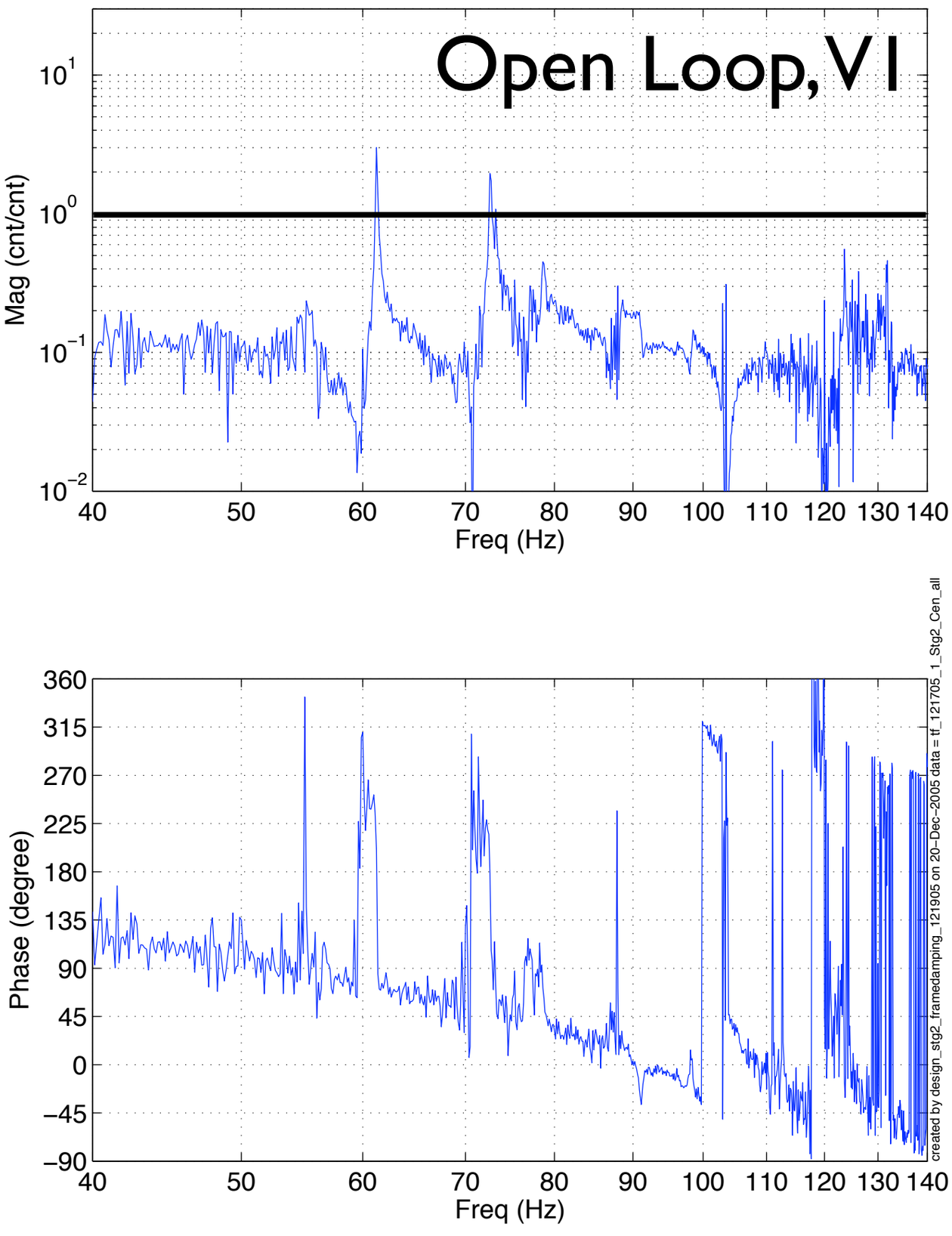
- remember:
  - isolation controls notch out the frame resonances,
  - high Q = passive transmission = poor isolation performance
- So: Use existing sensors and actuators to actively damp frame
- Configure as damping loops, gain > 1 only at peaks
- design in actuator basis, parallel to existing damping loops
- use 3 vertical GS-13/ actuator pairs on stage 2
  (well coupled to modes)
- works pretty well, but it took me a week to get right.

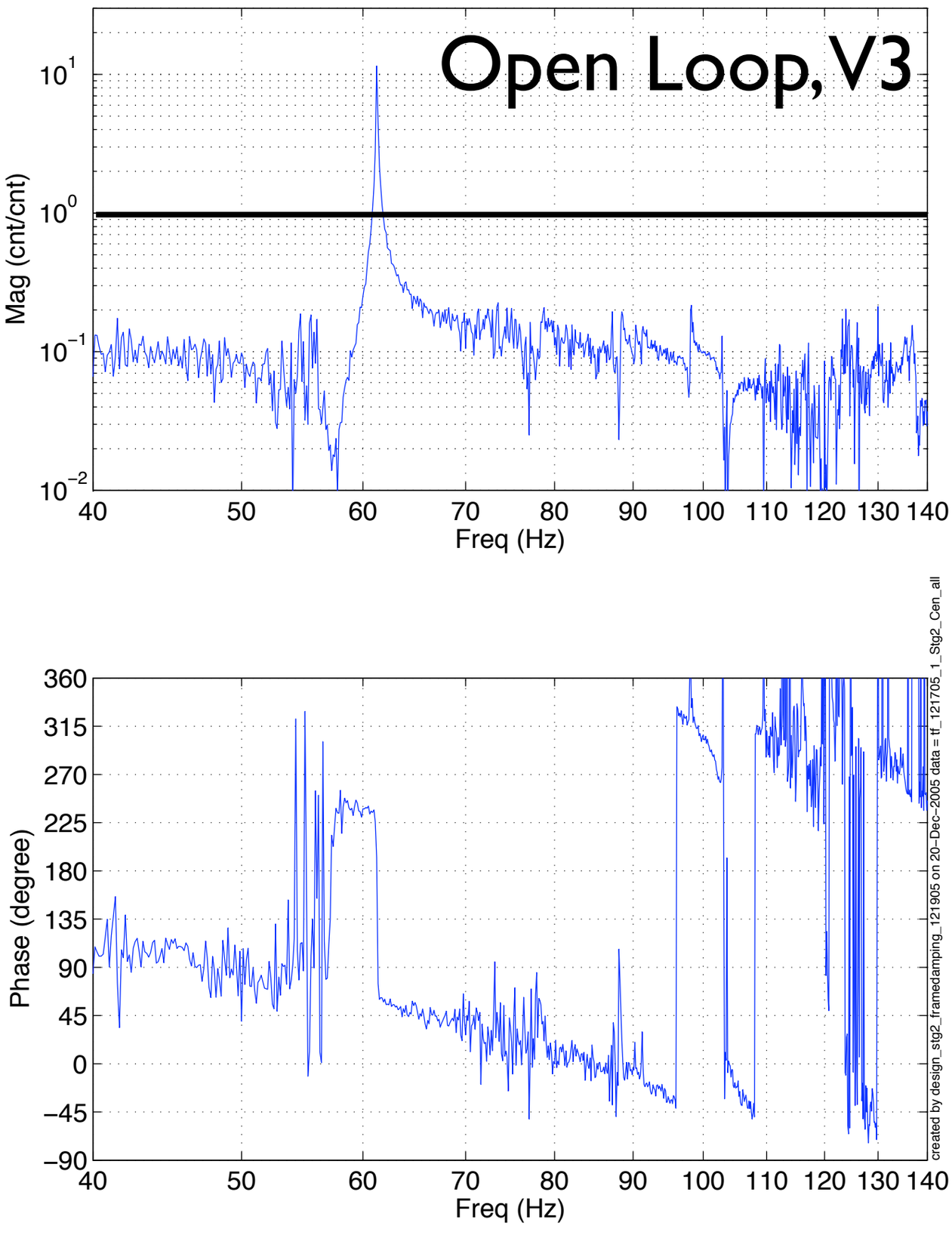
Simulink diagram with damping



stage 2 damping control, 6 parallel SISO loops, 1 sensor-> 1 actuator

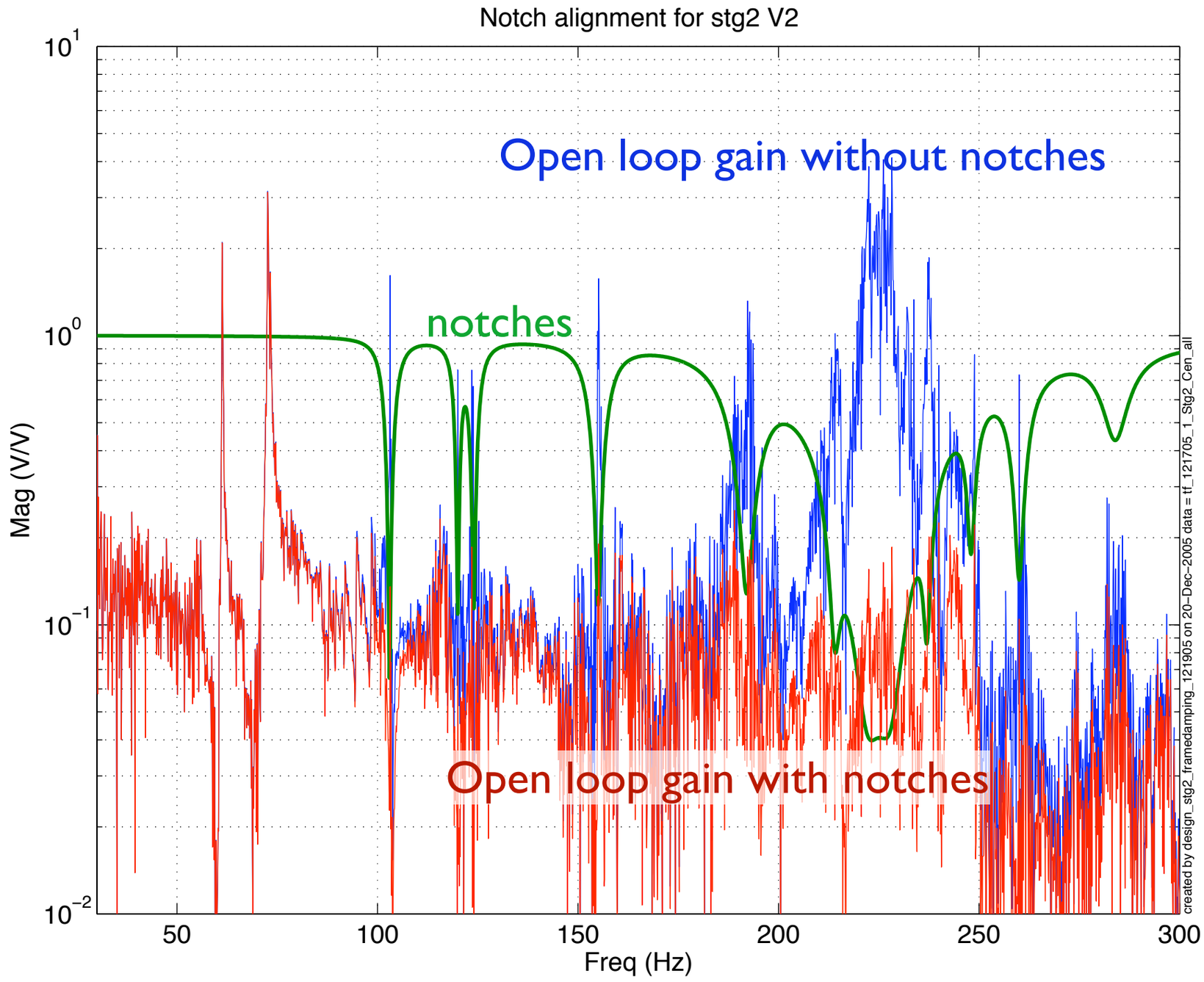
Damping control loops



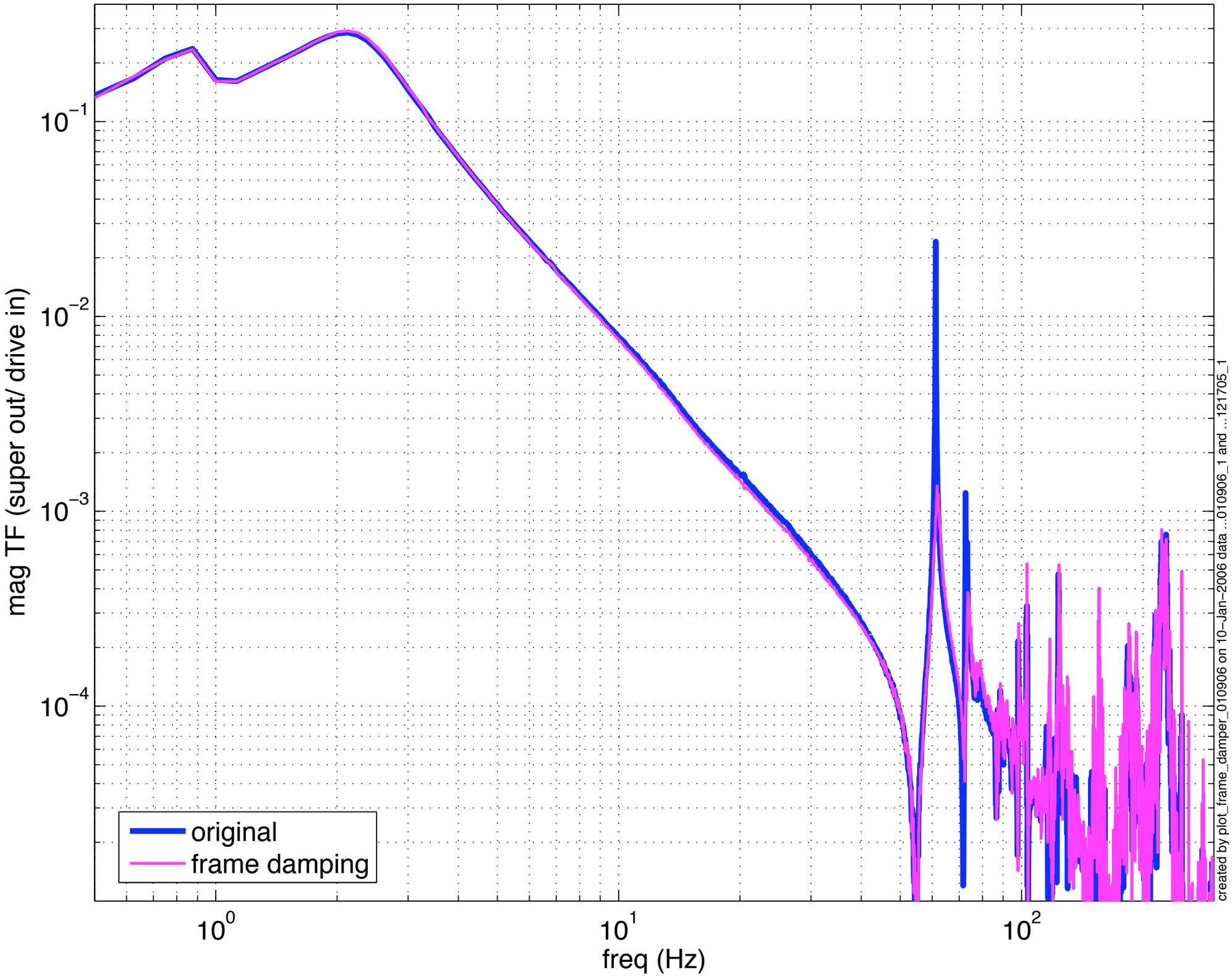


More irritating notches

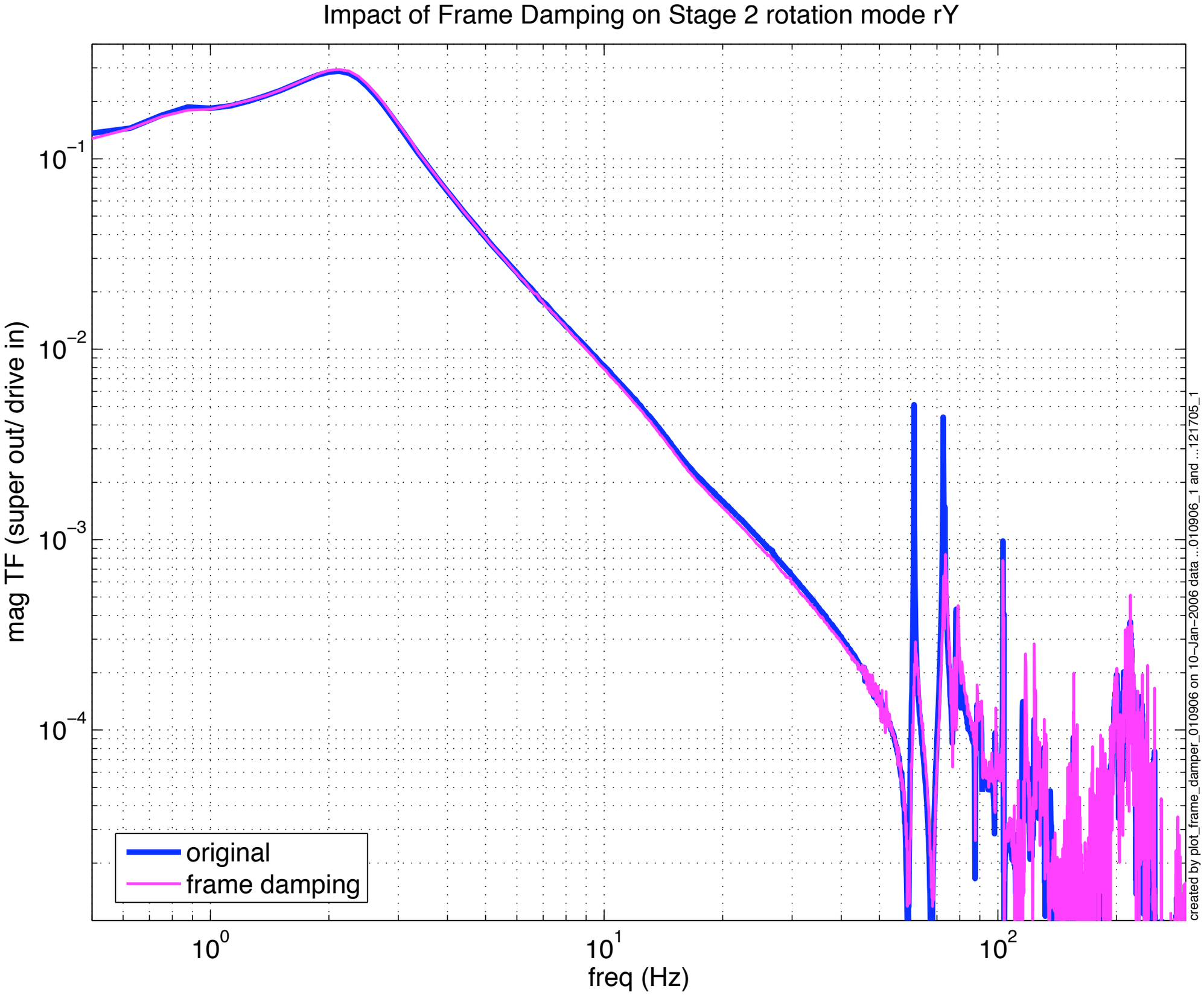
Large set of notches are necessary to insure minimal cross-coupling to other loops (and stability).



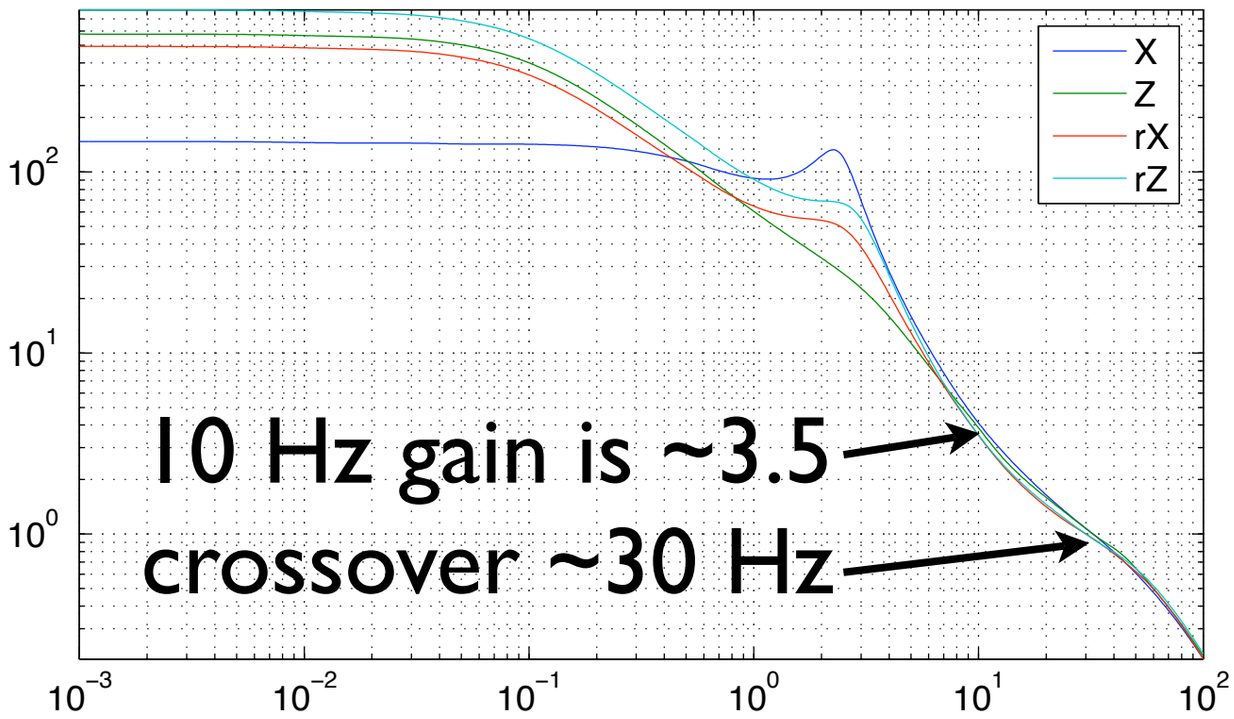
Results from notches, rX

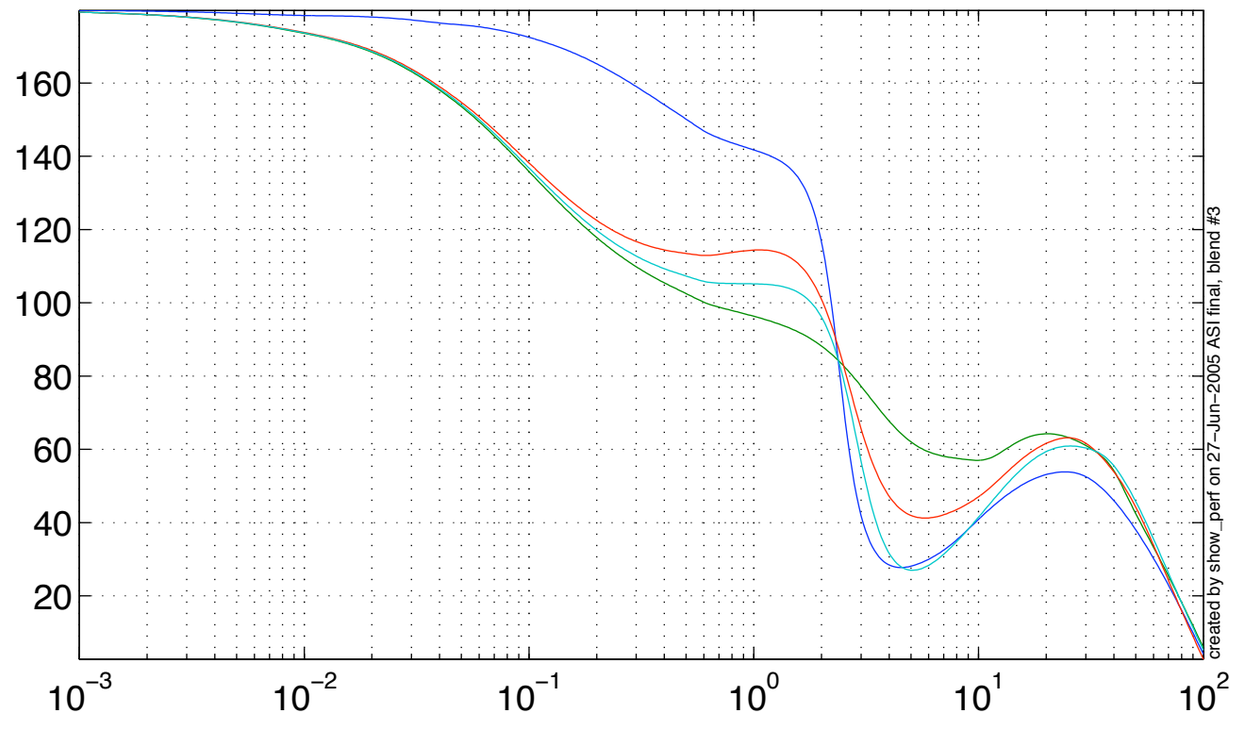


Results from notches, rY



From BSC model of May 2005

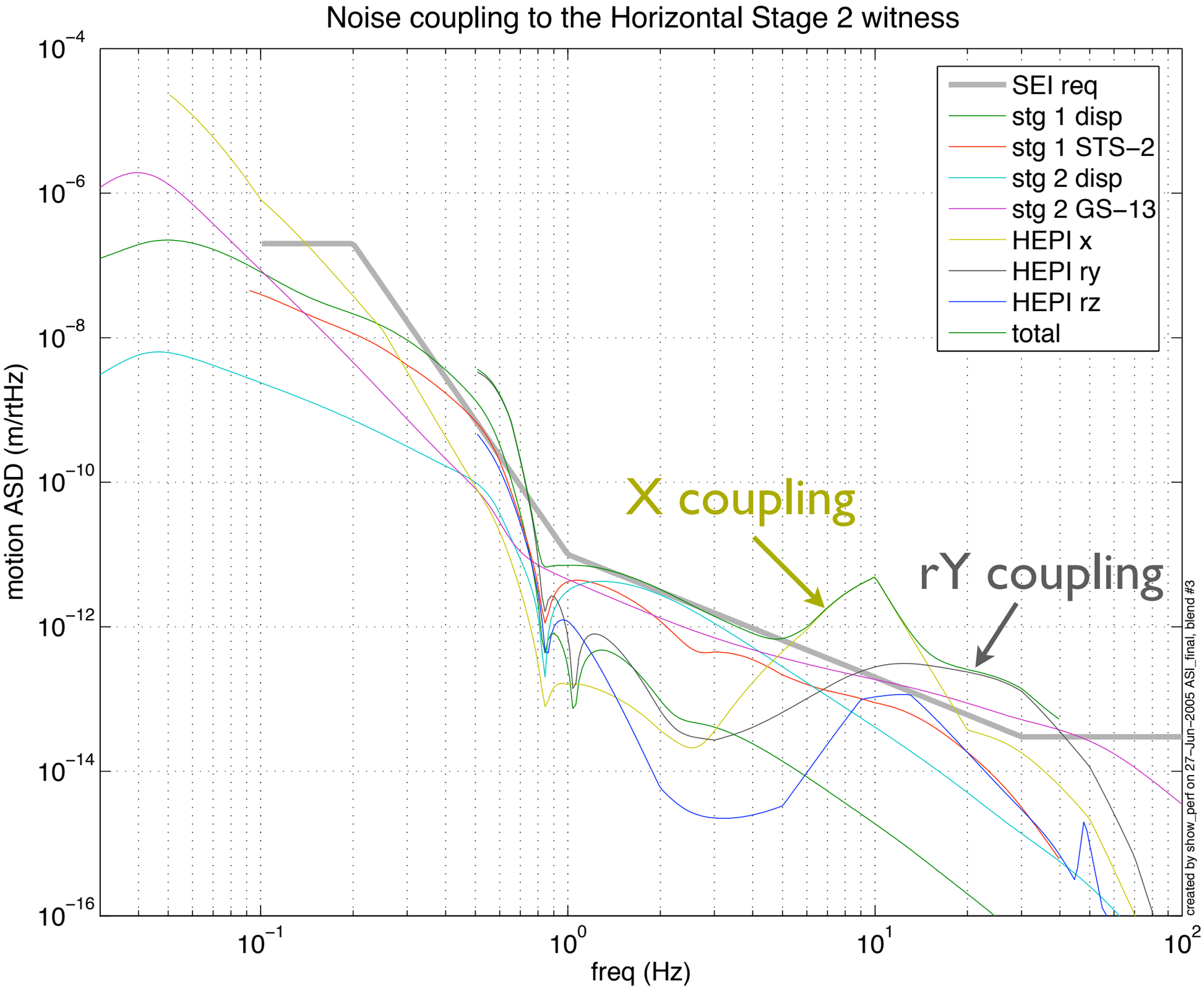




Current modes mean that the BSC system will not work quite as well as modeled.

Performance impact on BSC model about the same as the impact on the ETF.

From BSC model of May 2005

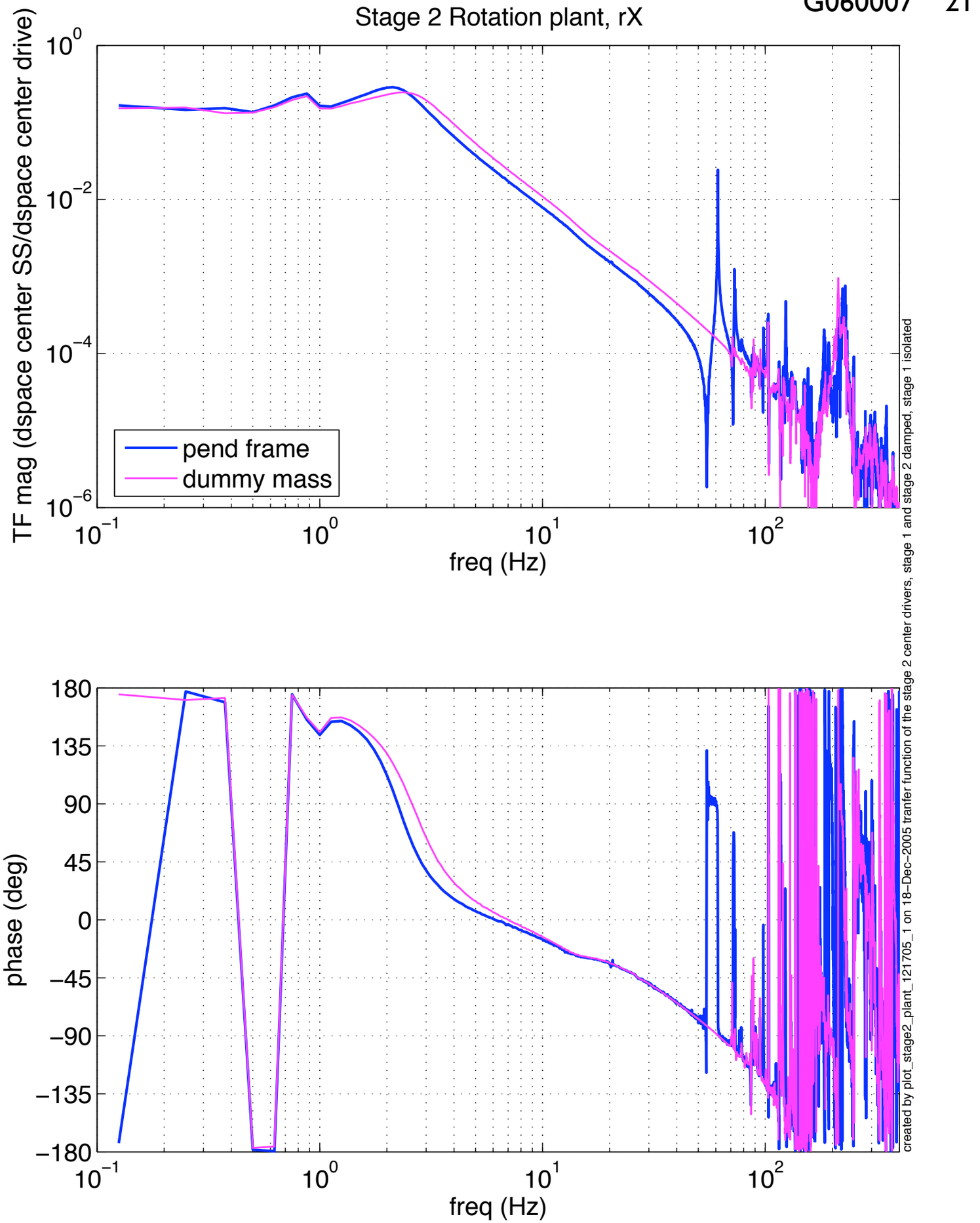


Thoughts

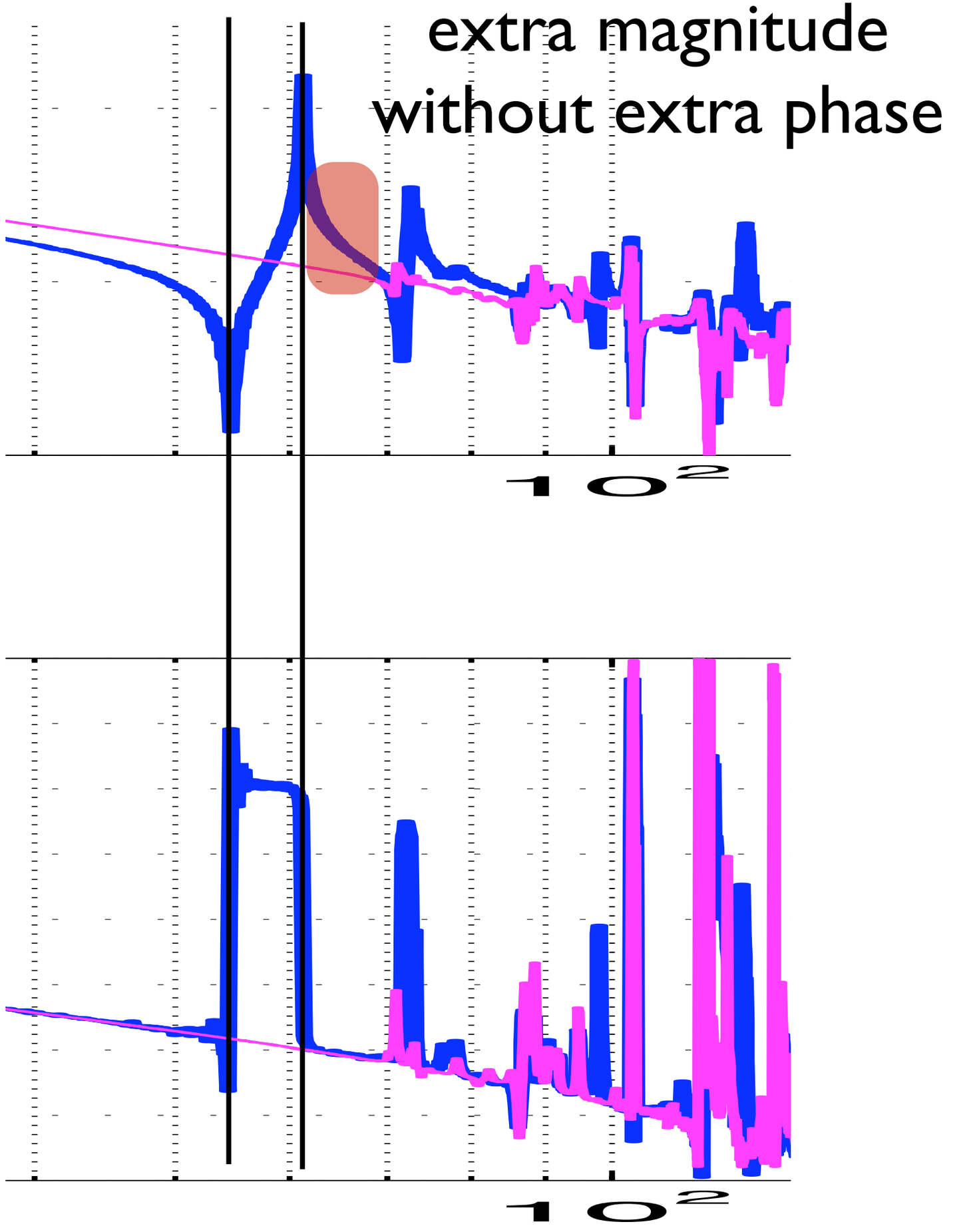
- Existing frame compromises the performance, but it can be made to work.
- Active damping of modes is possible, and it helps to some degree, but if we don't have to use it, we shouldn't.
- Work to be done:
  - Calum wants to replace lower structure with dummy masses to look at the impact on the resonances.
- Have abandoned:
  - put system in vacuum to measure real performance
  - turn on isolation controls for stage 2 x, y, z, rz
  - add extra sensor to tip of frame to better measure modes.

More Data

rX with phase



rX detail with phase



Servo for rX with phase