Improving DARM with ISI→ SUS feedforward

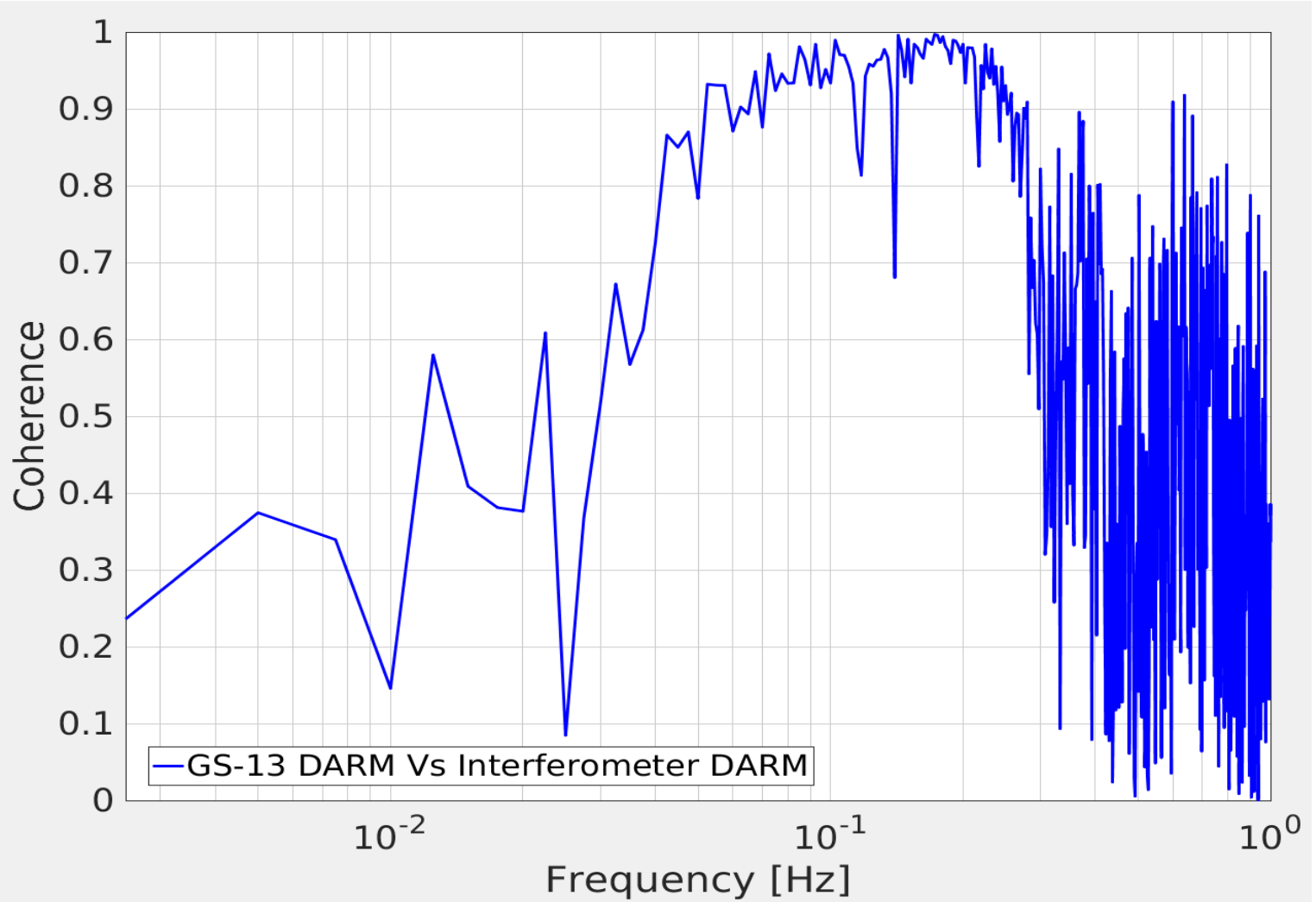
Edgard Bonilla

LVC Sonoma 2018

Outline

- Motivation
- Effects of a top mass length feedforward.
- Removing the cross coupling to pitch at the top mass.
- Sensitivity of the cross couplings

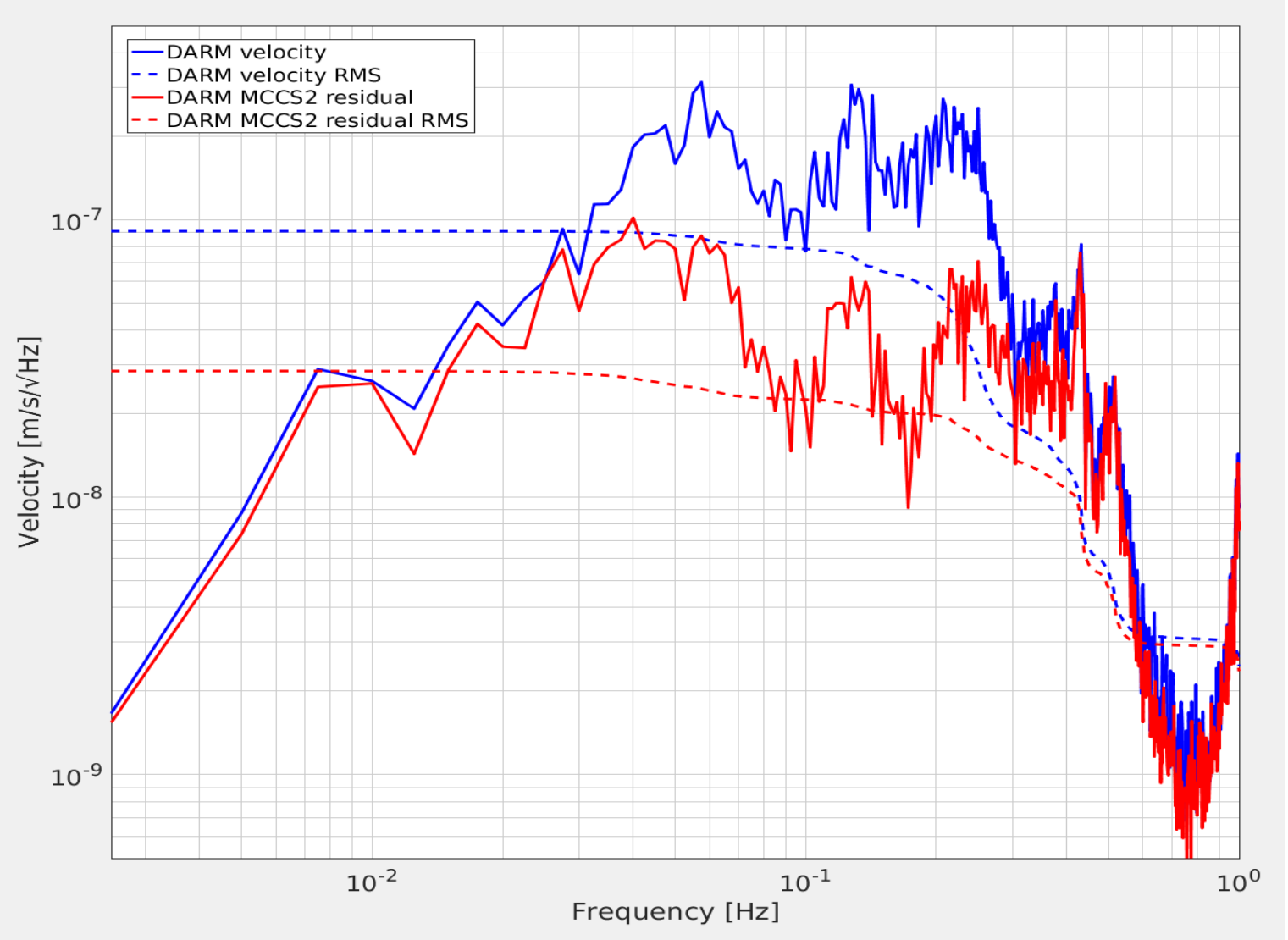
Coherence of DARM and GS13 DARM



High coherence from 60 – 300 mHz

Credit: Conor Mow-Lowry

Removal of the coherent GS13 signal

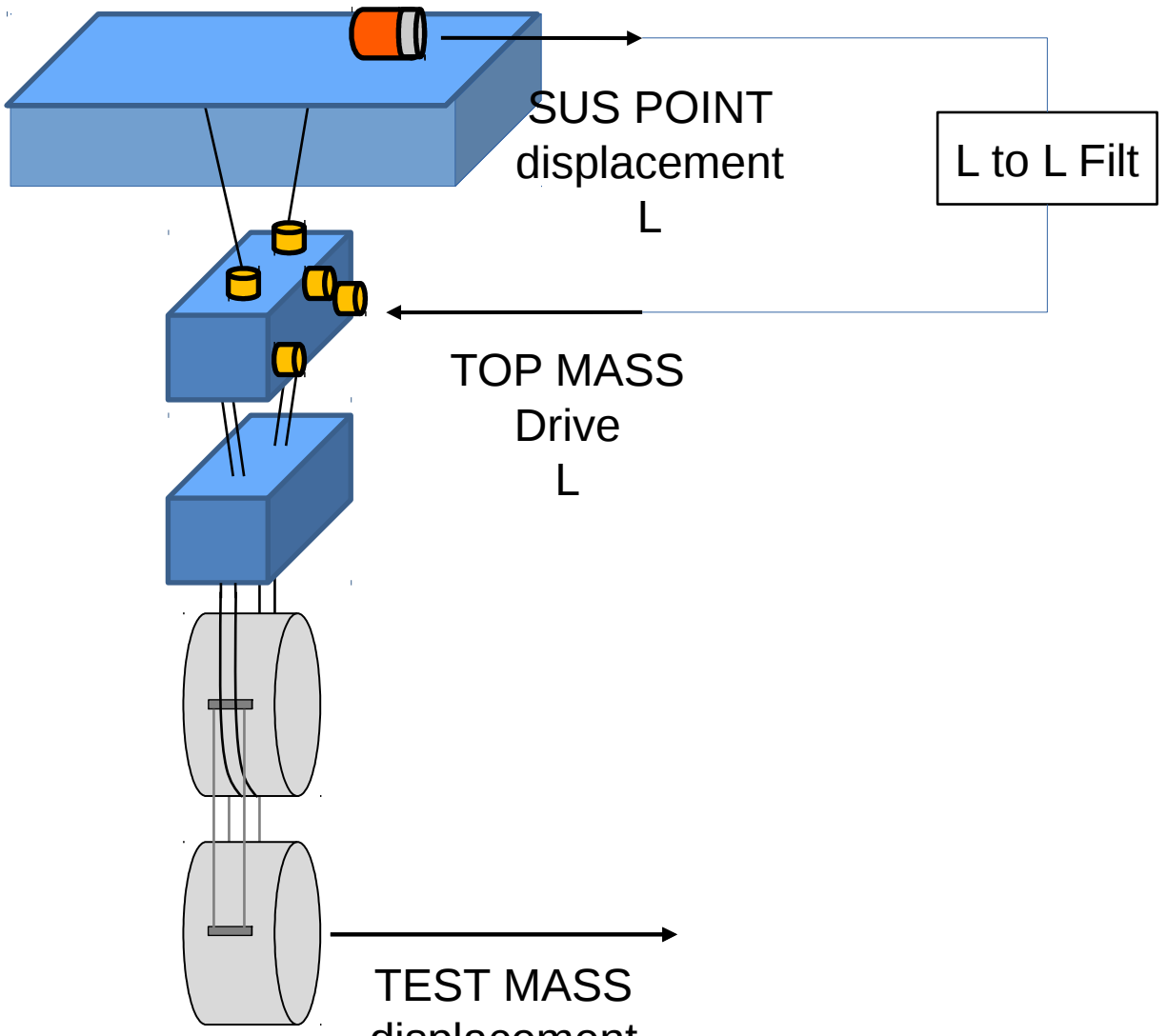


Credit: Conor Mow-Lowry

Summary (so far)

- ✓ The sus point GS13 signal can be used to improve DARM from .1 to .3 Hz.

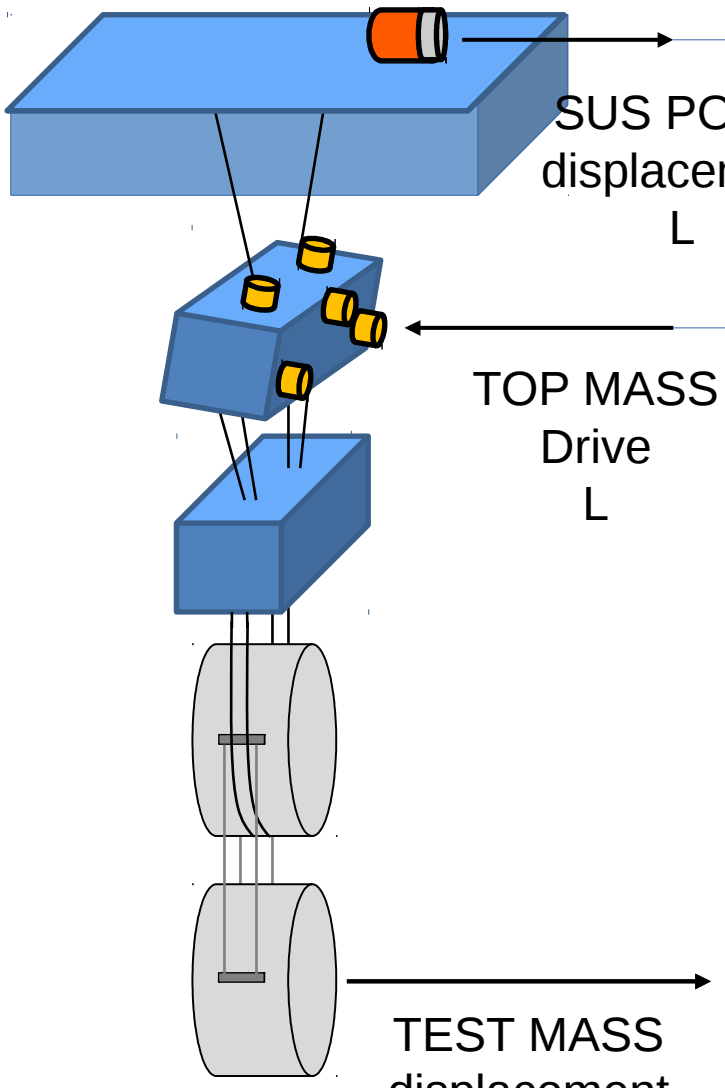
Length Feedforward



= GS13

= Top Mass OSEM

Length Feedforward

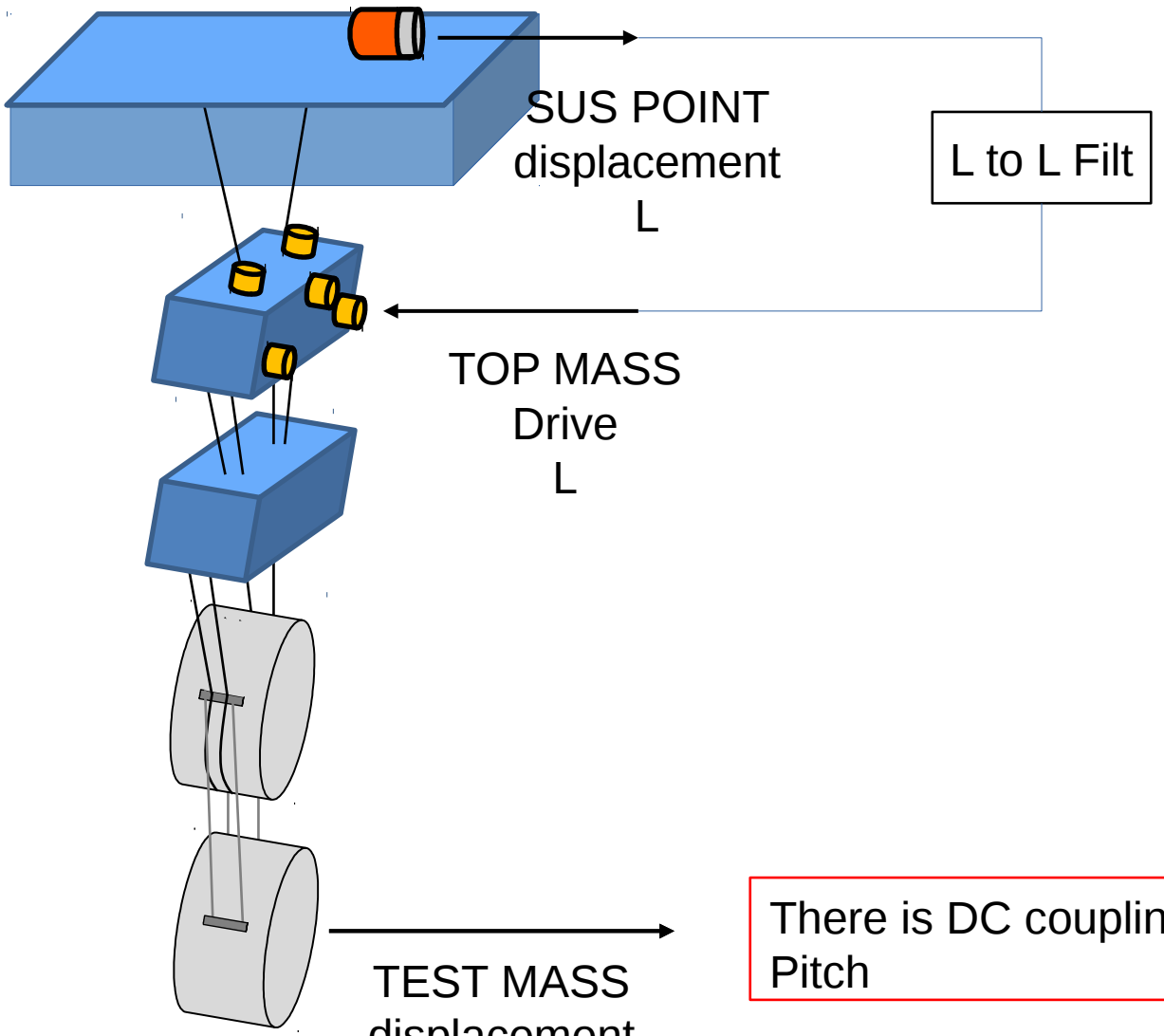


This compensation has unintended consequences...

= GS13

= Top Mass OSEM

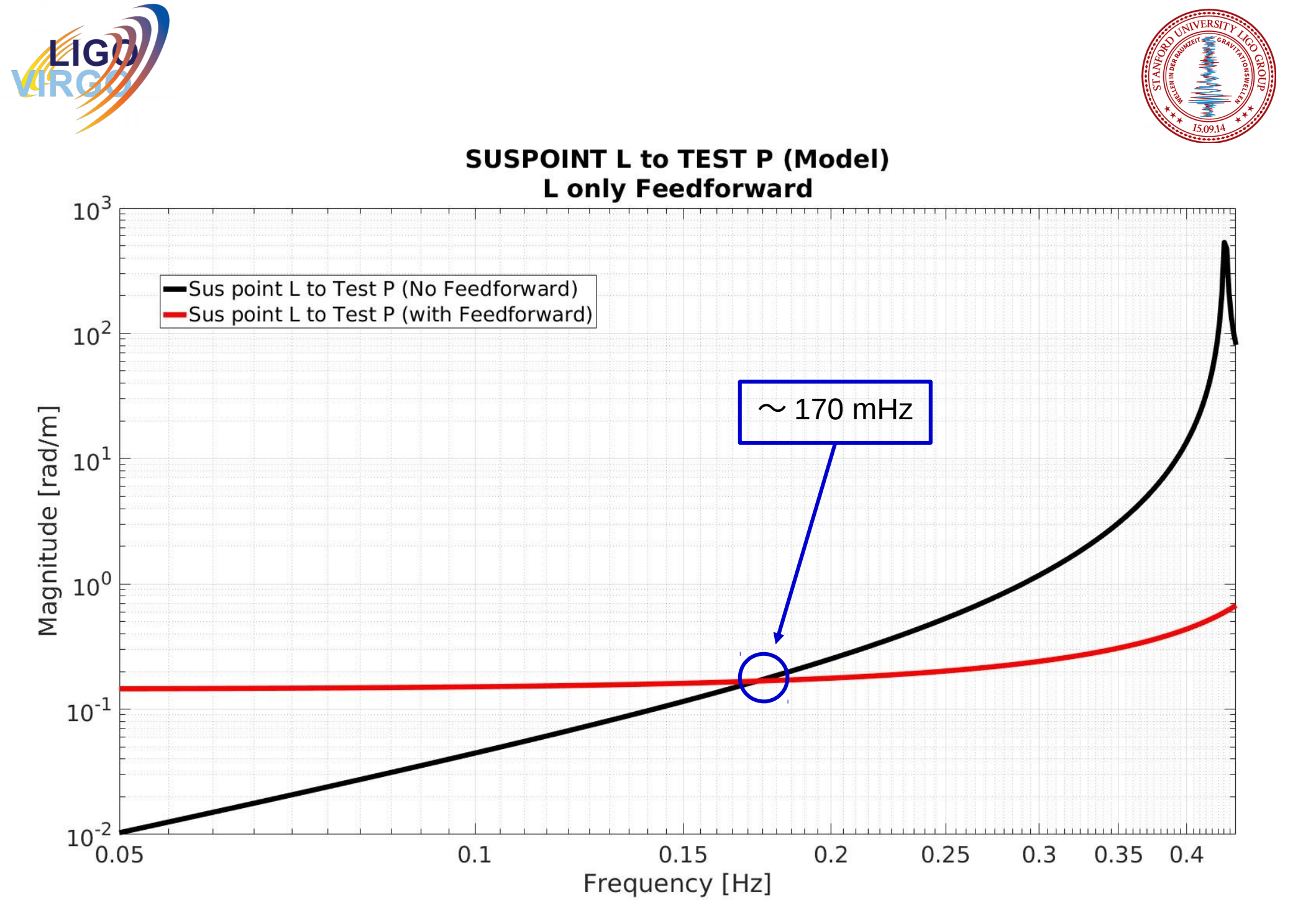
Length Feedforward



There is DC coupling to Pitch

= GS13

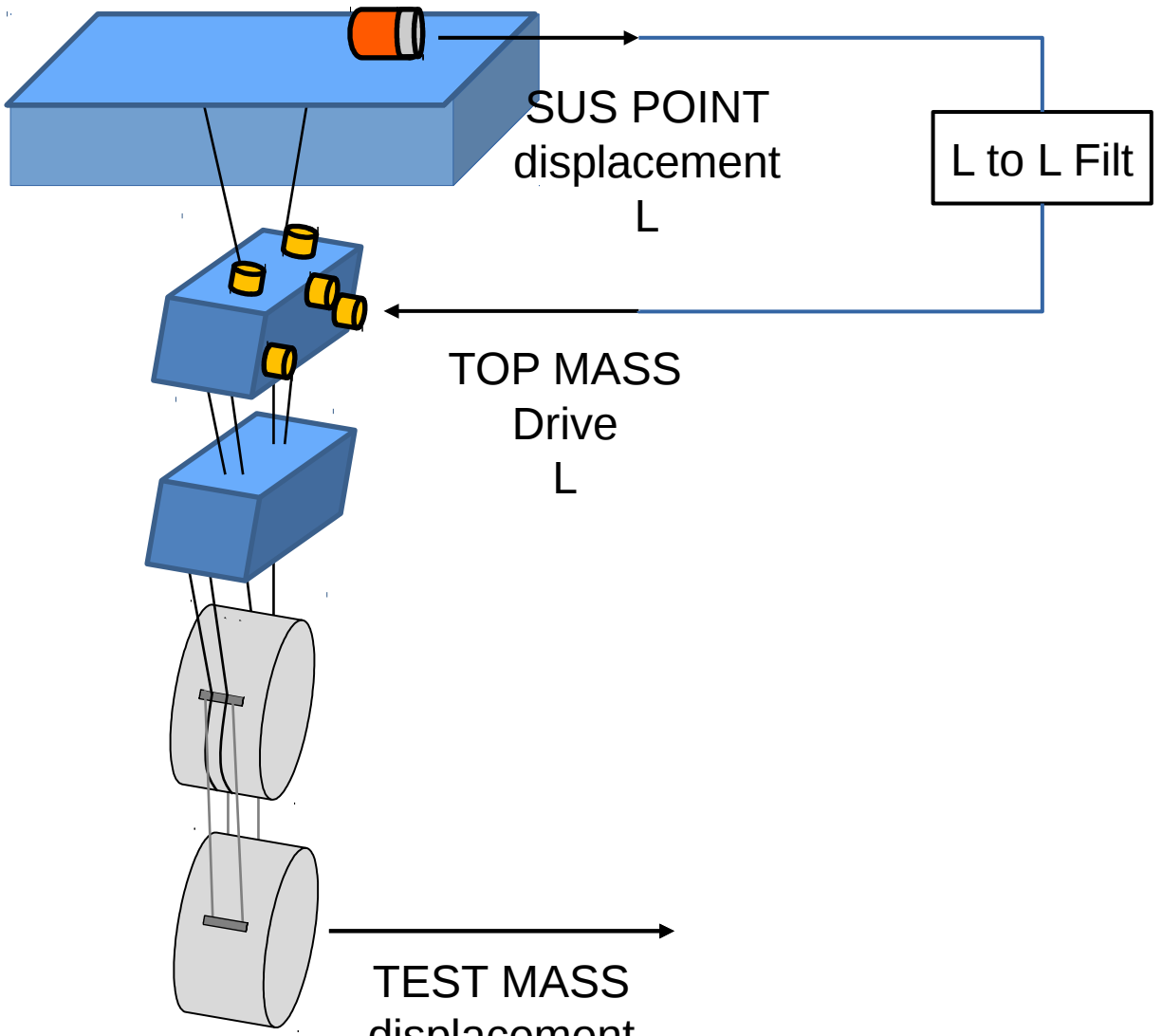
= Top Mass OSEM


SUSPOINT L to TEST P (Model)
L only Feedforward
Sus point L to Test P (No Feedforward)
Sus point L to Test P (with Feedforward)
~ 170 mHz
Magnitude [rad/m]
Frequency [Hz]
10^3
10^2
10^1
10^0
10^-1
10^-2
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

Summary (so far)

- ✓ The sus point GS13 signal can be used to improve DARM from .1 to .3 Hz.
- ✓ The Feedforward filter cannot ignore the pitch cross coupling at the Top Mass.

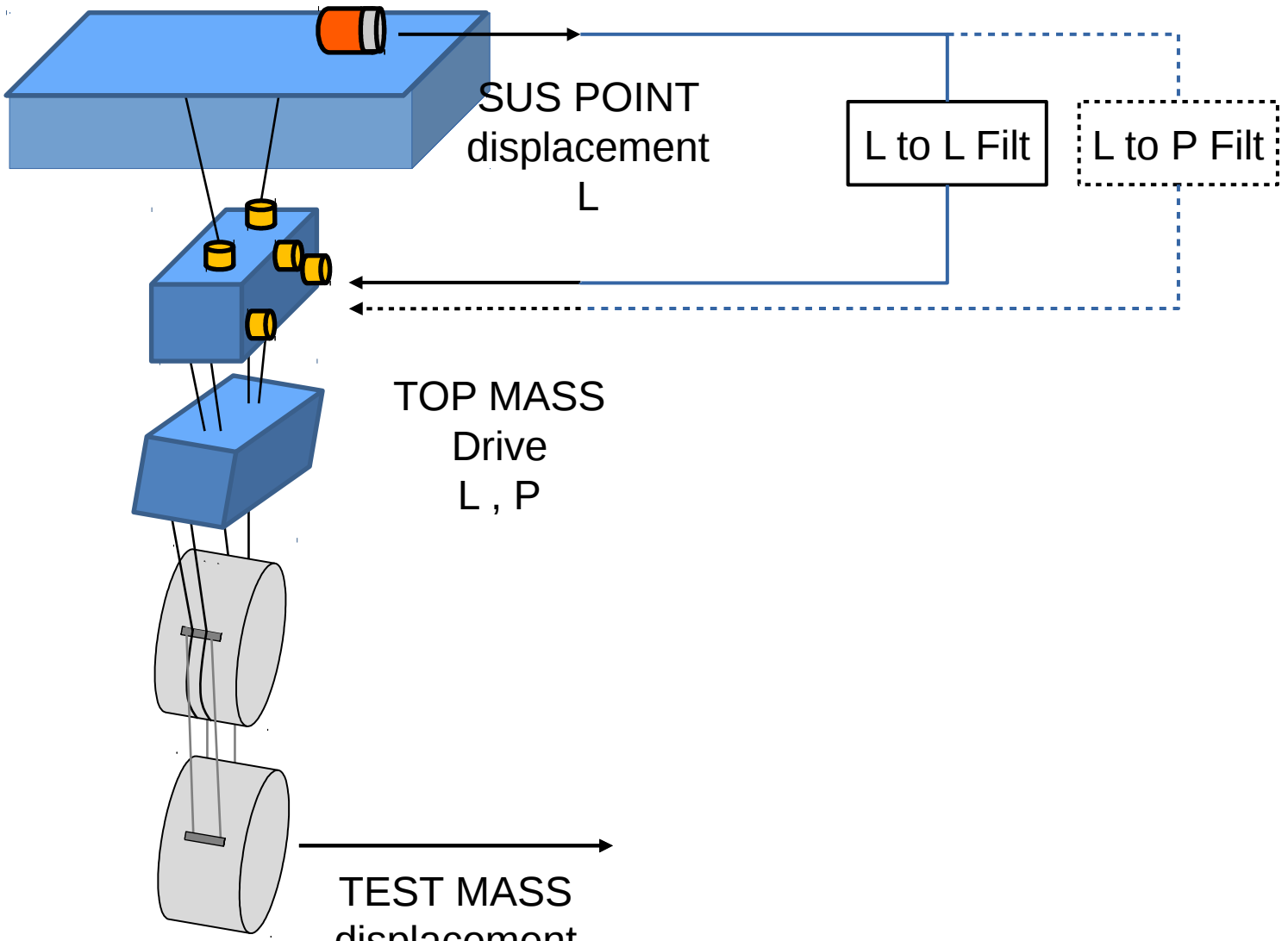
Pitch Compensation



= GS13

= Top Mass OSEM

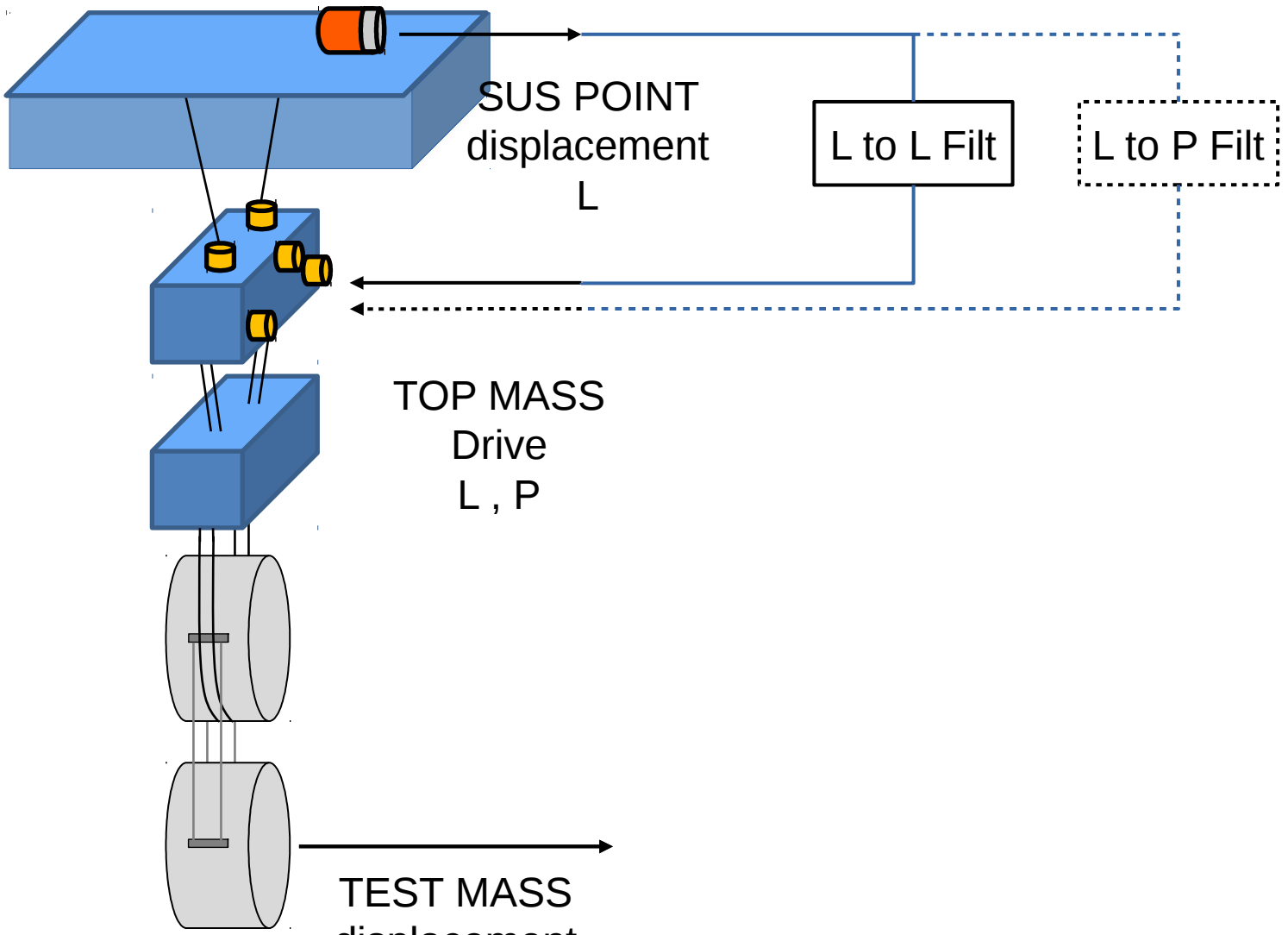
Pitch Compensation



= GS13

= Top Mass OSEM

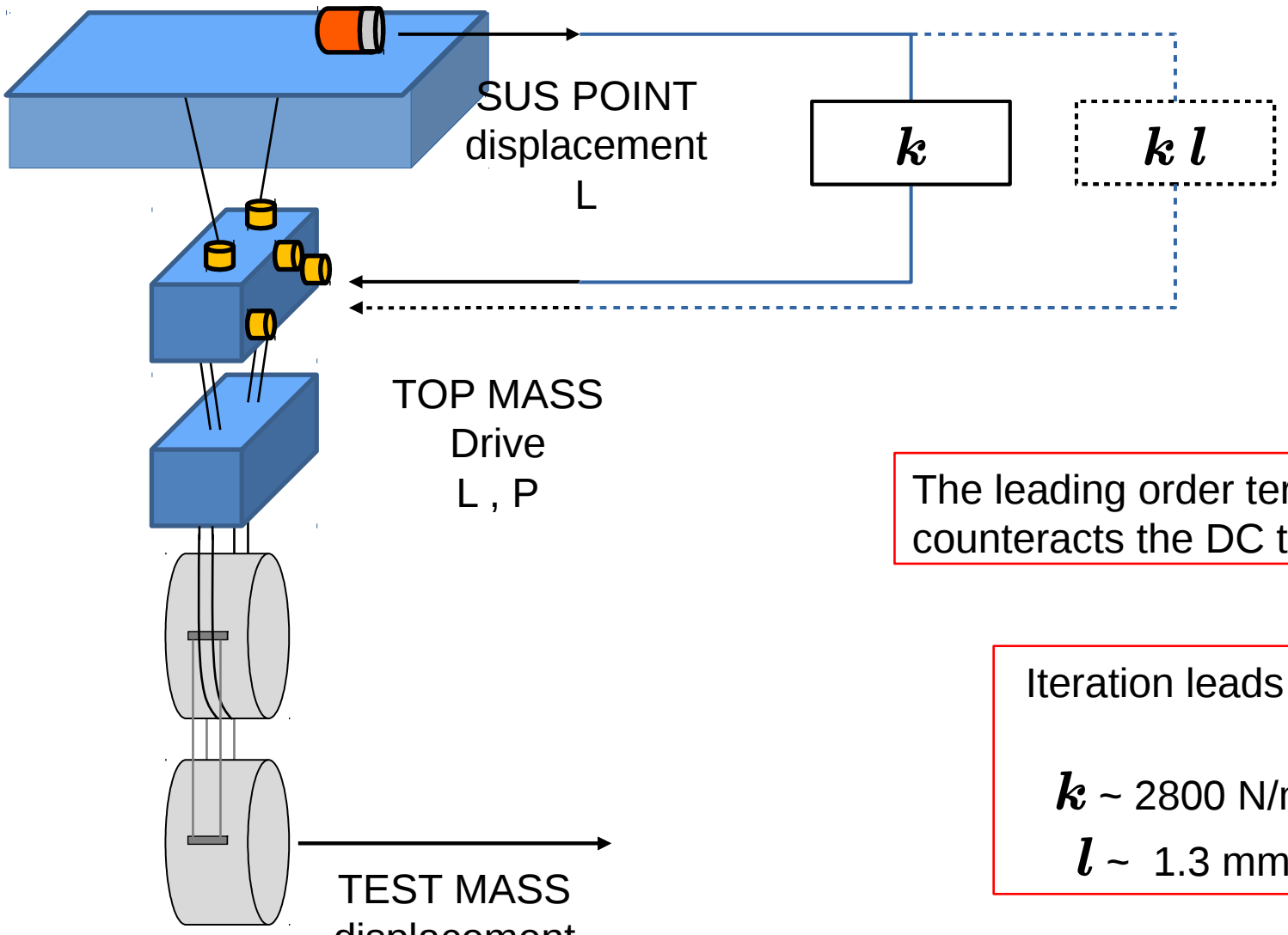
Pitch Compensation



= GS13

= Top Mass OSEM

Pitch Compensation



The leading order term counteracts the DC torque

Iteration leads to:

k ~ 2800 N/m

l ~ 1.3 mm

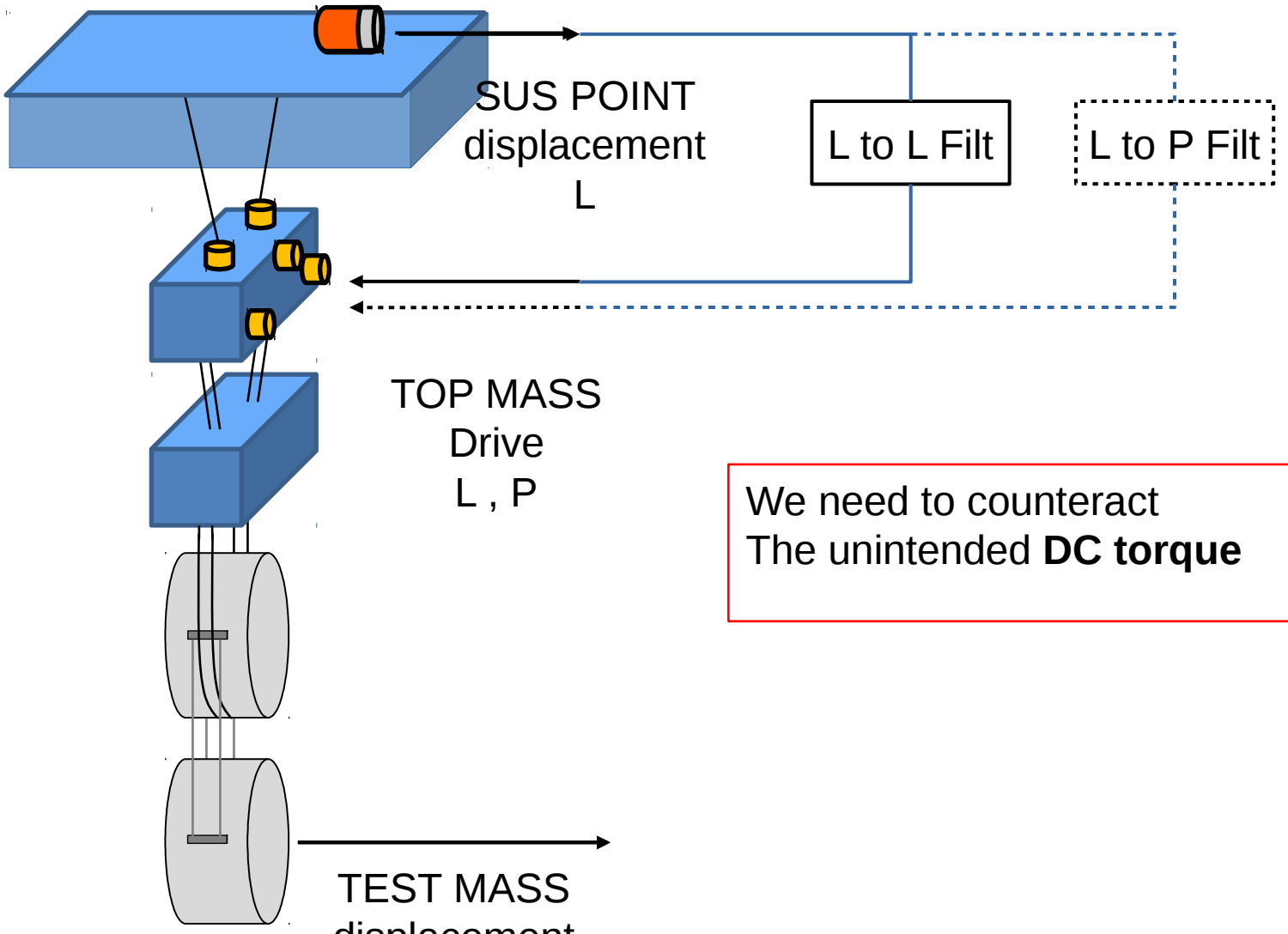
= GS13

= Top Mass OSEM

Summary (so far)

- The sus point GS13 signal can be used to improve DARM from .1 to .3 Hz.
- The Feedforward filter cannot ignore the pitch cross coupling at the Top Mass.
- It is sufficient to isolate the top mass in L and P

DC Pitch estimation



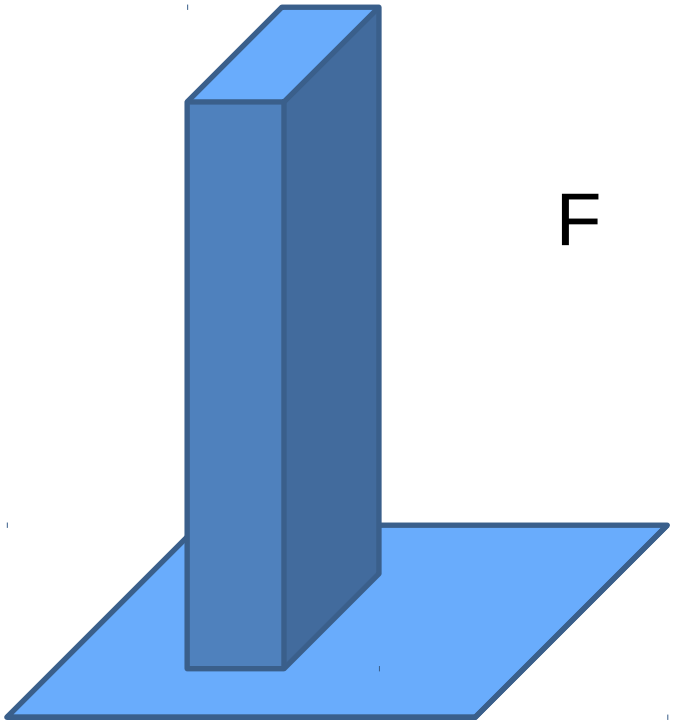
We need to counteract
The unintended **DC torque**

= GS13

= Top Mass OSEM

DC Pitch estimation

Let’s abstract the problem:

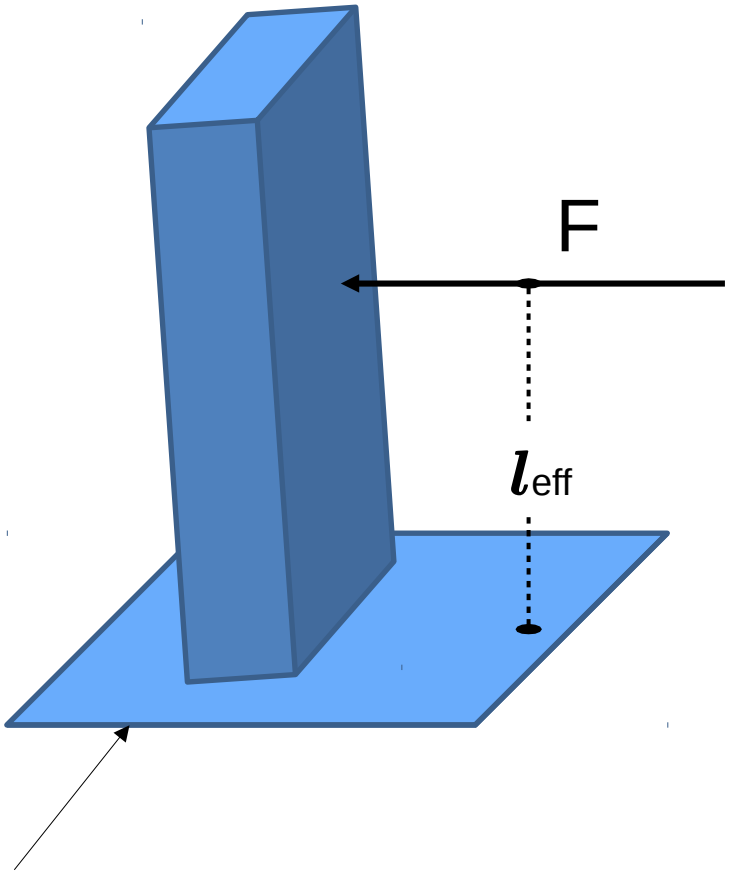


F

Pivot Plane

DC Pitch estimation

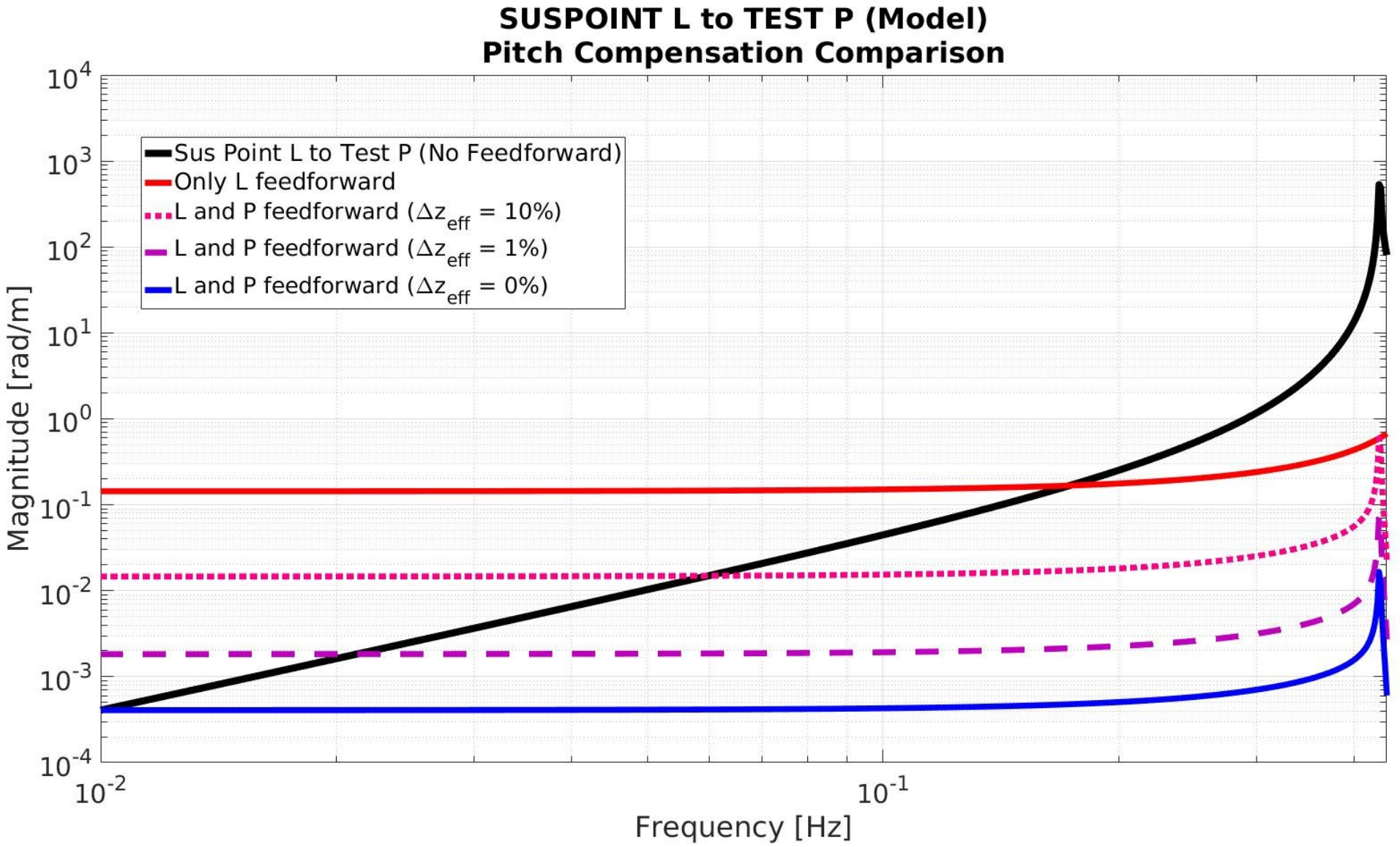
Let's abstract the problem:

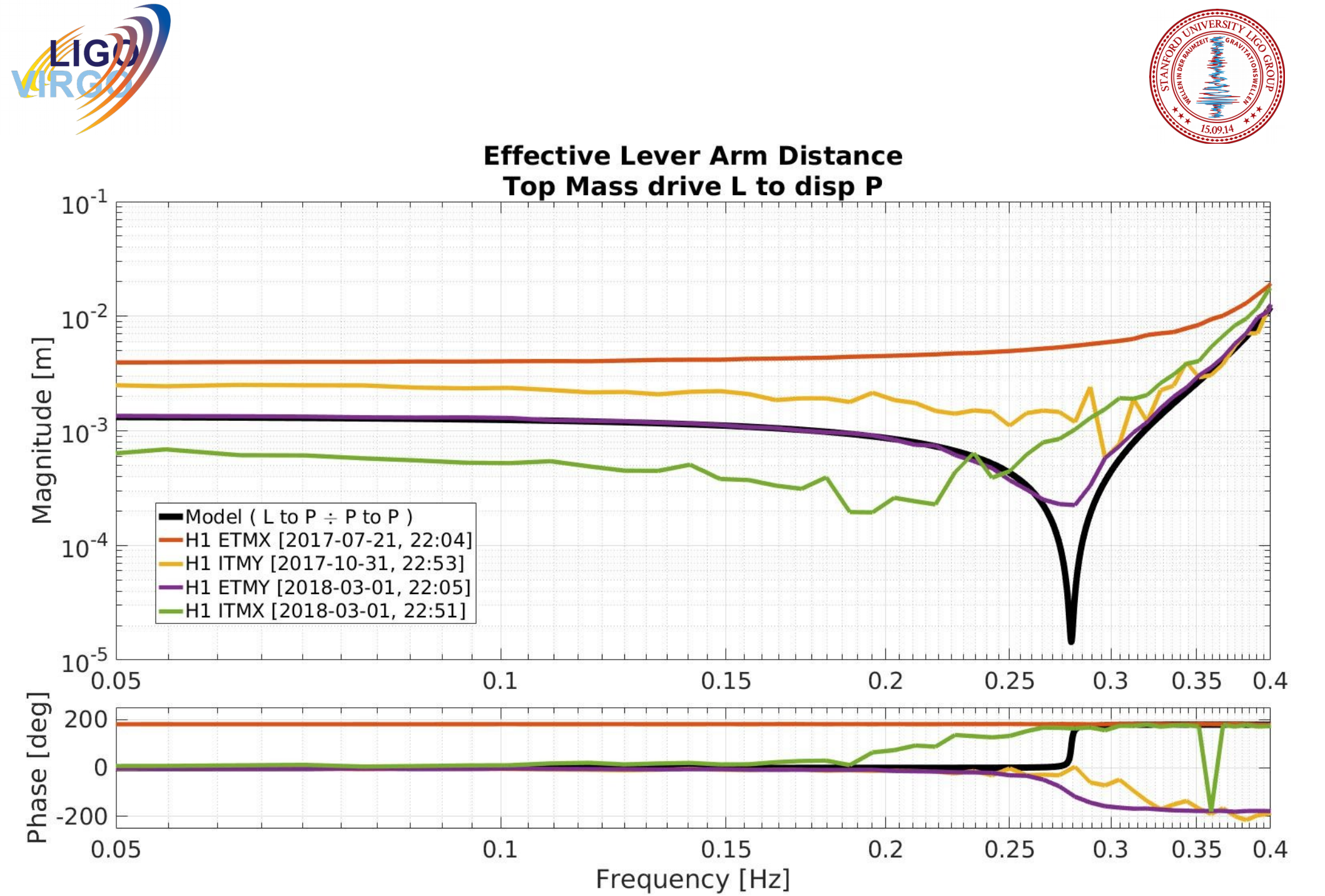


The torque generated by the force F is given by:

$$\tau = l_{eff} F$$

Approximate at DC


SUSPOINT L to TEST P (Model)
Pitch Compensation Comparison
Sus Point L to Test P (No Feedforward)
Only L feedforward
L and P feedforward (Δz_eff = 10%)
L and P feedforward (Δz_eff = 1%)
L and P feedforward (Δz_eff = 0%)
Magnitude [rad/m]
Frequency [Hz]
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-2
10^-1


Effective Lever Arm Distance
Top Mass drive L to disp P
Magnitude [m]
Phase [deg]
Frequency [Hz]
Model (L to P ÷ P to P)
H1 ETMX [2017-07-21, 22:04]
H1 ITMY [2017-10-31, 22:53]
H1 ETMY [2018-03-01, 22:05]
H1 ITMX [2018-03-01, 22:51]

Summary

- The sus point GS13 signal can be used to improve DARM from .1 to .3 Hz.
- The Feedforward filter cannot ignore the pitch cross coupling at the Top Mass.
- It is sufficient to isolate the top mass in L and P to get a similar performance at the test mass.
- The L-P coupling cannot be treated with an unified scheme for all QUADs.

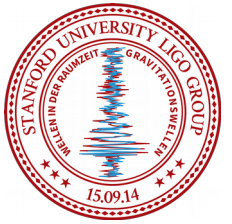
Summary

- The sus point GS13 signal can be used to improve DARM from .1 to .3 Hz.
- The Feedforward filter cannot ignore the pitch cross coupling at the Top Mass.
- It is sufficient to isolate the top mass in L and P to get a similar performance at the test mass.
- The L-P coupling cannot be treated with an unified scheme for all QUADs.
- If these cross couplings are time dependent, pure Feedforward might be impractical

Next Steps

- Study in more detail the possible physical origin of the cross coupling variations across different QUADs.
- Evaluate the time dependence of z_{eff} for each individual QUAD using collected data.
- Explore the idea of counteracting the torque in the top mass in a different way.


LIGO
VIRGO


STANFORD UNIVERSITY LIGO GROUP
WELLEN IN DER RAUMZEIT
GRAVITATIONSWELLEN
15.09.14

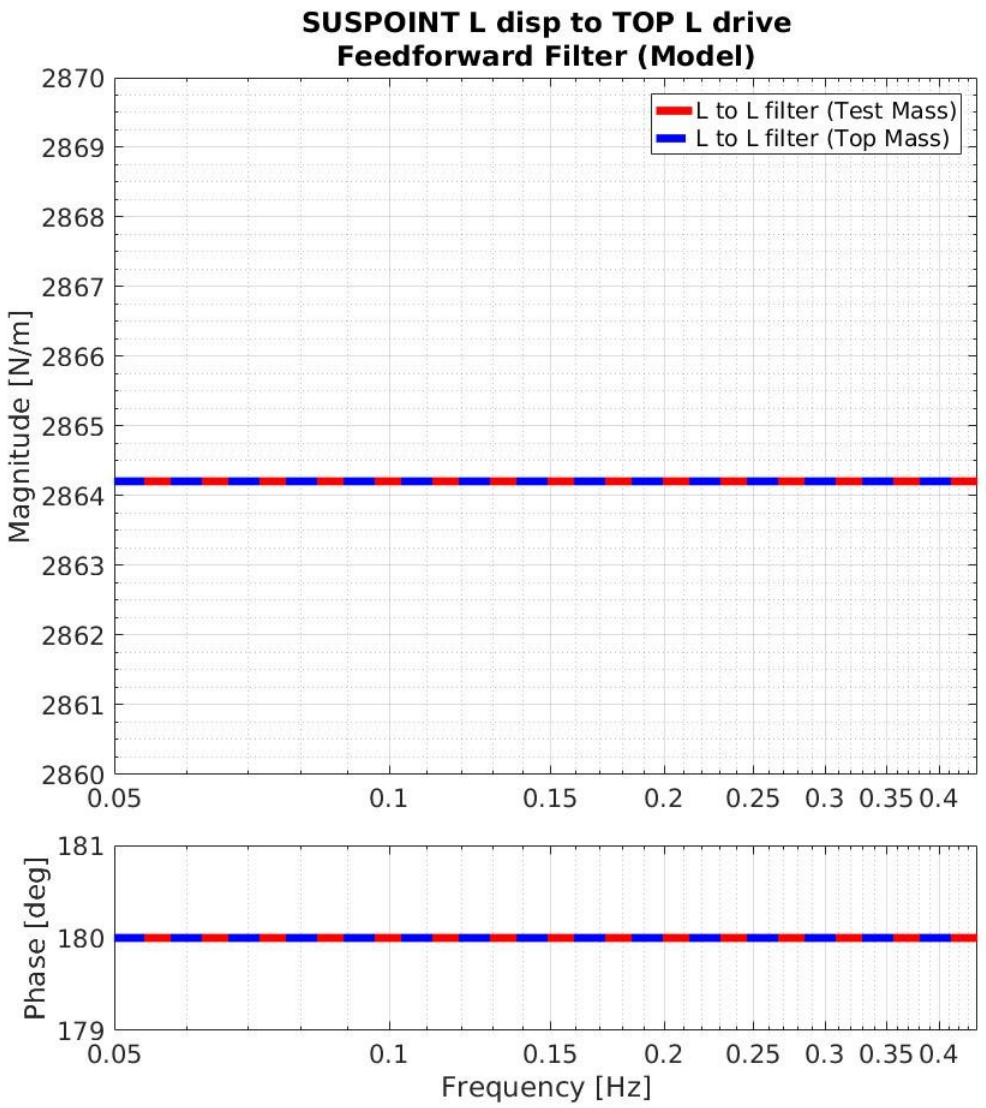
Q & A

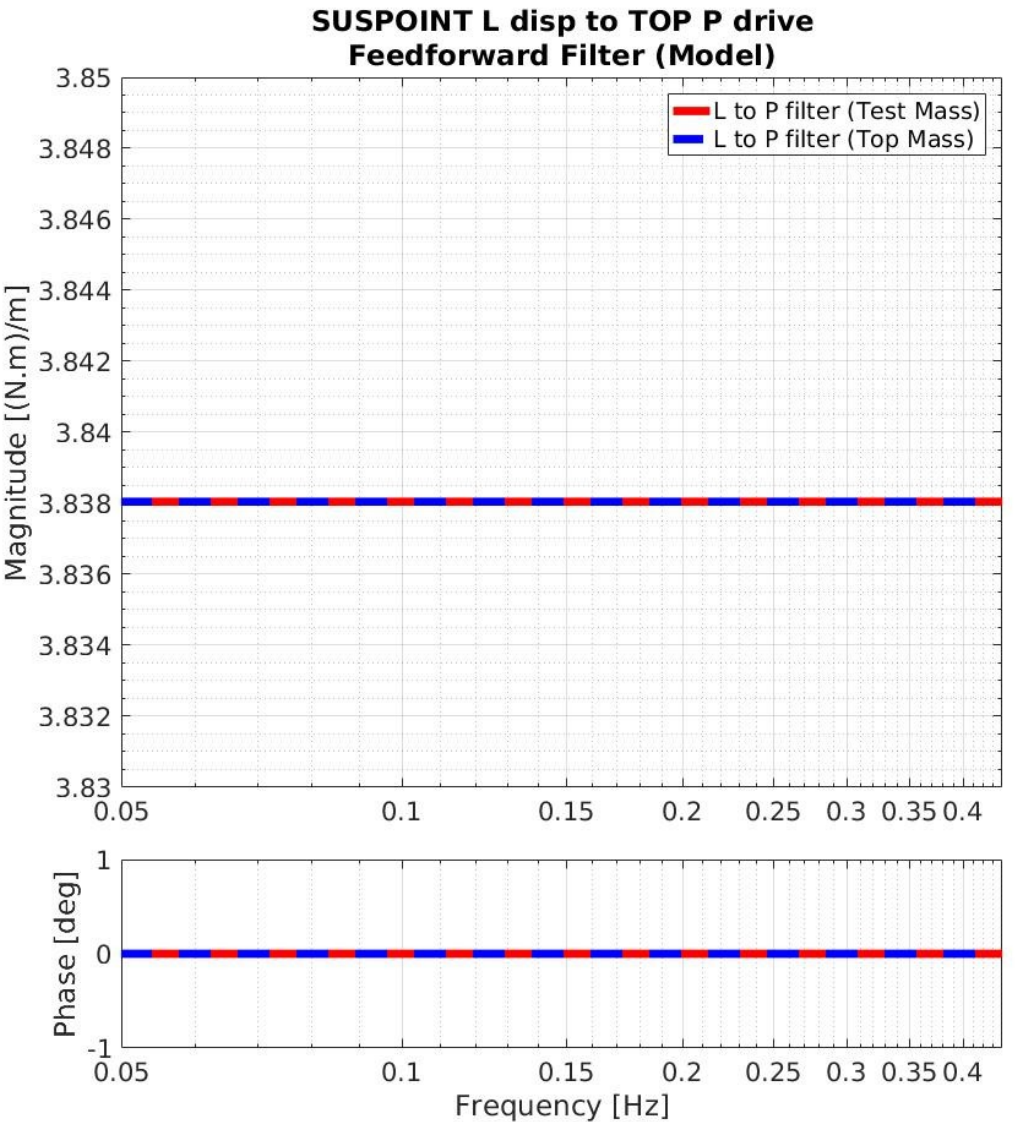
Summary

- The sus point GS13 signal can be used to improve DARM from .1 to .3 Hz.
- The Feedforward filter cannot ignore cross coupling to Pitch at the top mass.
- It is enough to isolate the top mass in Length and Pitch
- The L-P coupling cannot be treated with an unified scheme for all SUS.
- If these cross couplings are time dependent, pure Feedforward might be impractical

Next Steps

- Study in more detail the possible physical origin of the cross coupling variations across different QUADs.
- Evaluate the time dependence of z_{eff} for each individual QUAD using collected data.
- Explore the idea of counteracting the torque in the top mass in a different way.


SUSPOINT L disp to TOP L drive
Feedforward Filter (Model)
L to L filter (Test Mass)
L to L filter (Top Mass)
Magnitude [N/m]
2870
2869
2868
2867
2866
2865
2864
2863
2862
2861
2860
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Phase [deg]
181
180
179
Frequency [Hz]


SUSPOINT L disp to TOP P drive
Feedforward Filter (Model)
L to P filter (Test Mass)
L to P filter (Top Mass)
Magnitude [(N.m)/m]
3.85
3.848
3.846
3.844
3.842
3.84
3.838
3.836
3.834
3.832
3.83
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Phase [deg]
1
0
-1
Frequency [Hz]