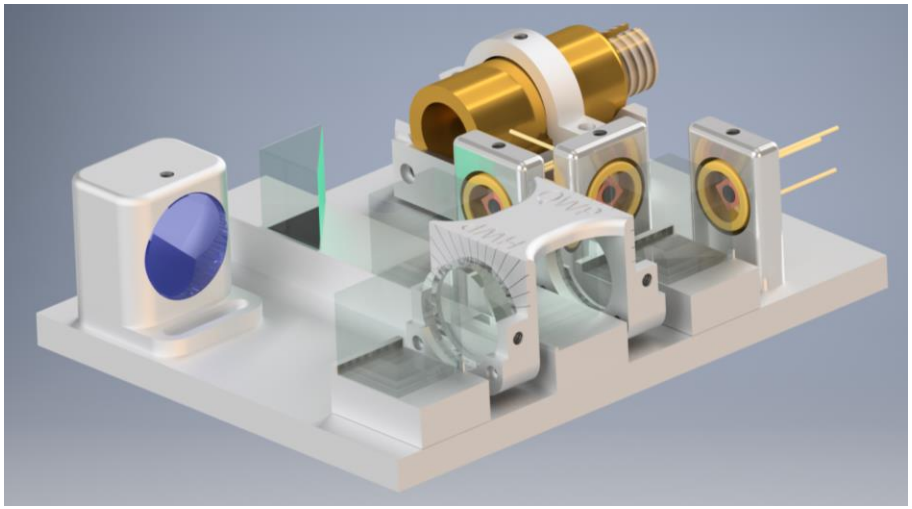
Interferometric sensors for low frequency isolation and control



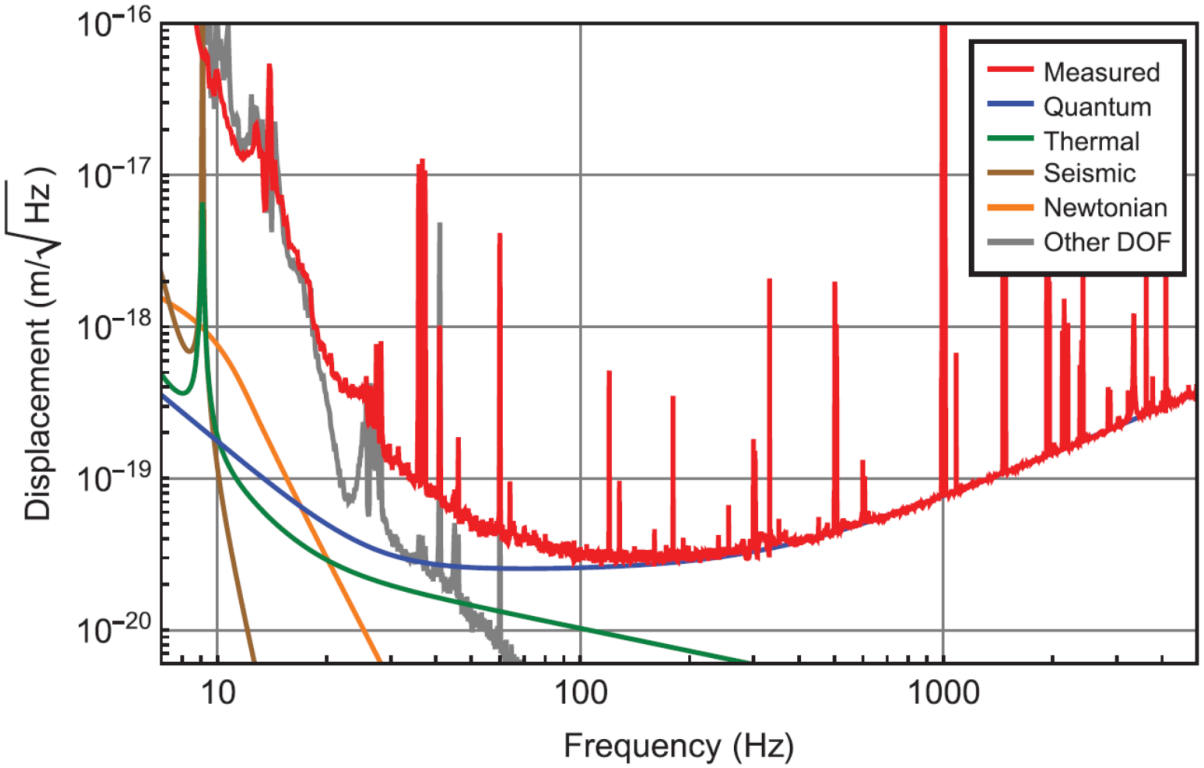
- **Sam Cooper**, Conor Mow-Lowry, Chris Collins, Leonid Prokhorov, Amit Ubhi, Denis Martynov, Chiara di Fronzo

UNIVERSITY OF BIRMINGHAM | INSTITUTE FOR GRAVITATIONAL WAVE ASTRONOMY

Breaking the seismic wall

Want to detect low frequency gravitational waves: intermediate mass black holes + early warning of mergers.

Limited by technical noise sub ~ 30Hz. Caused in part by residual ISI motion.



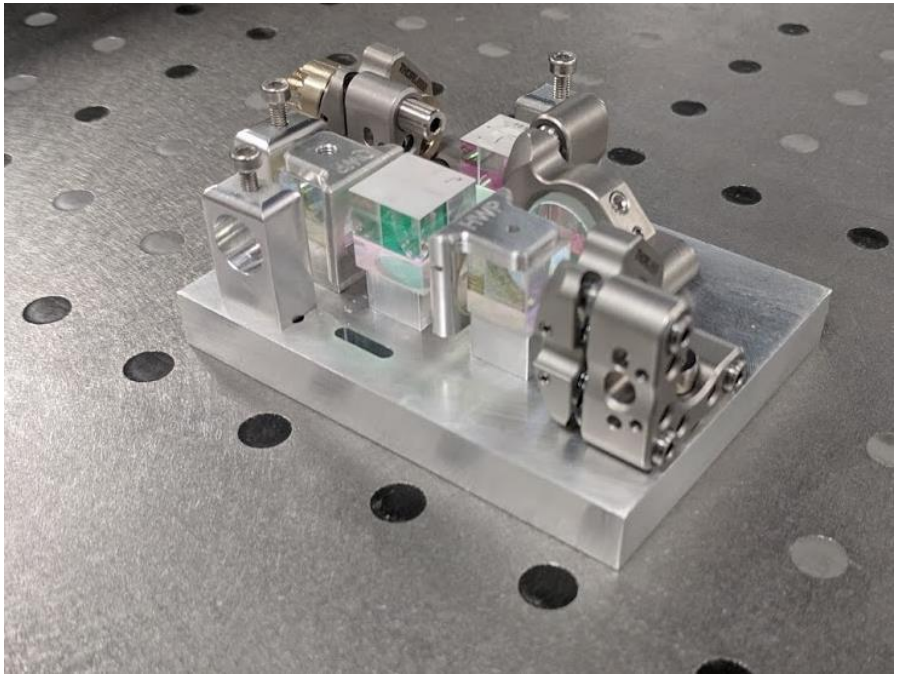
SRCL Note: T1900107

Breaking the seismic wall

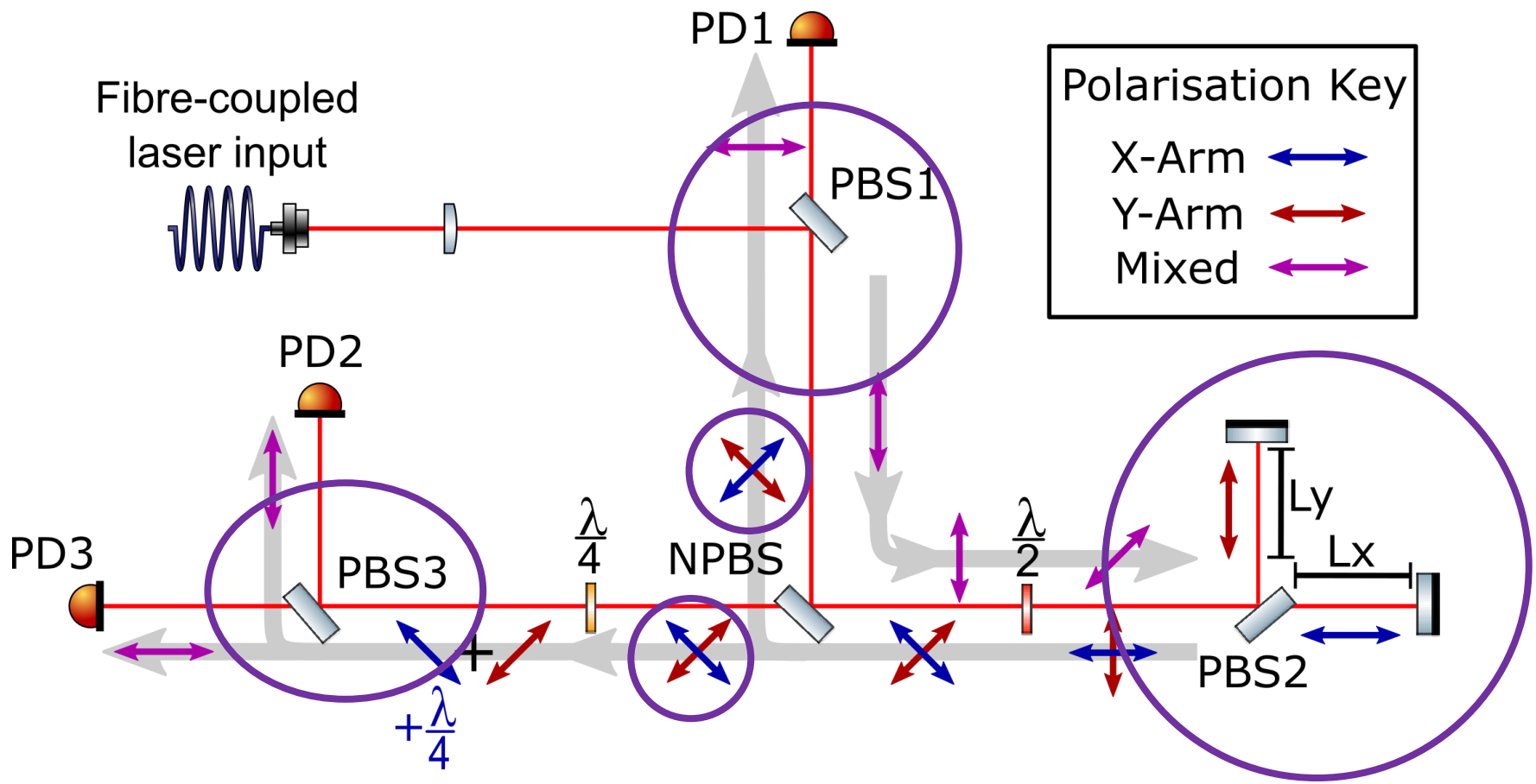
We have developed a tool that can fix this in two ways

1) Local damping of suspensions

2) Reducing ISI motion with new sensors

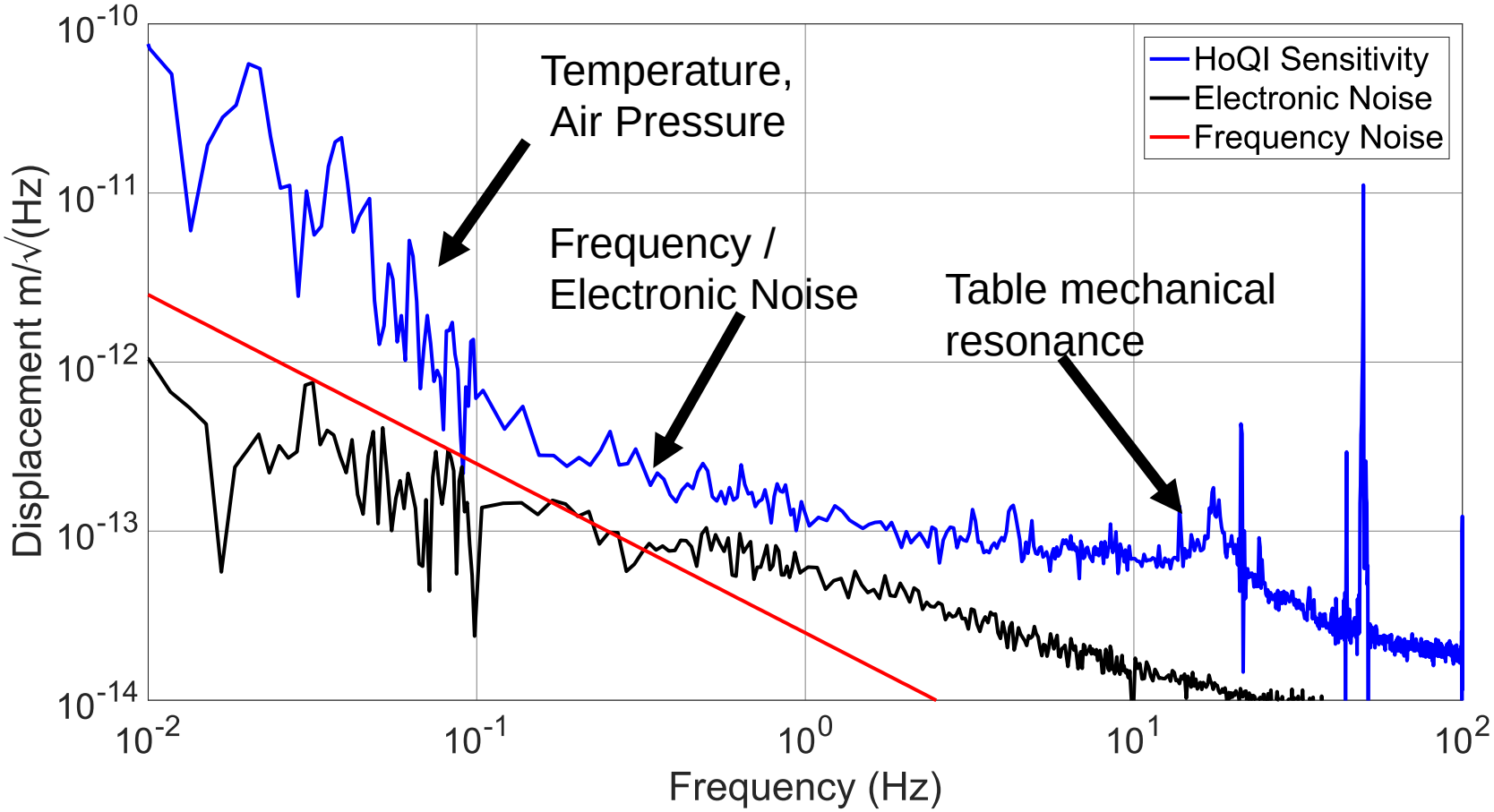


HoQI: HOmodyne Quadrature Interferometer



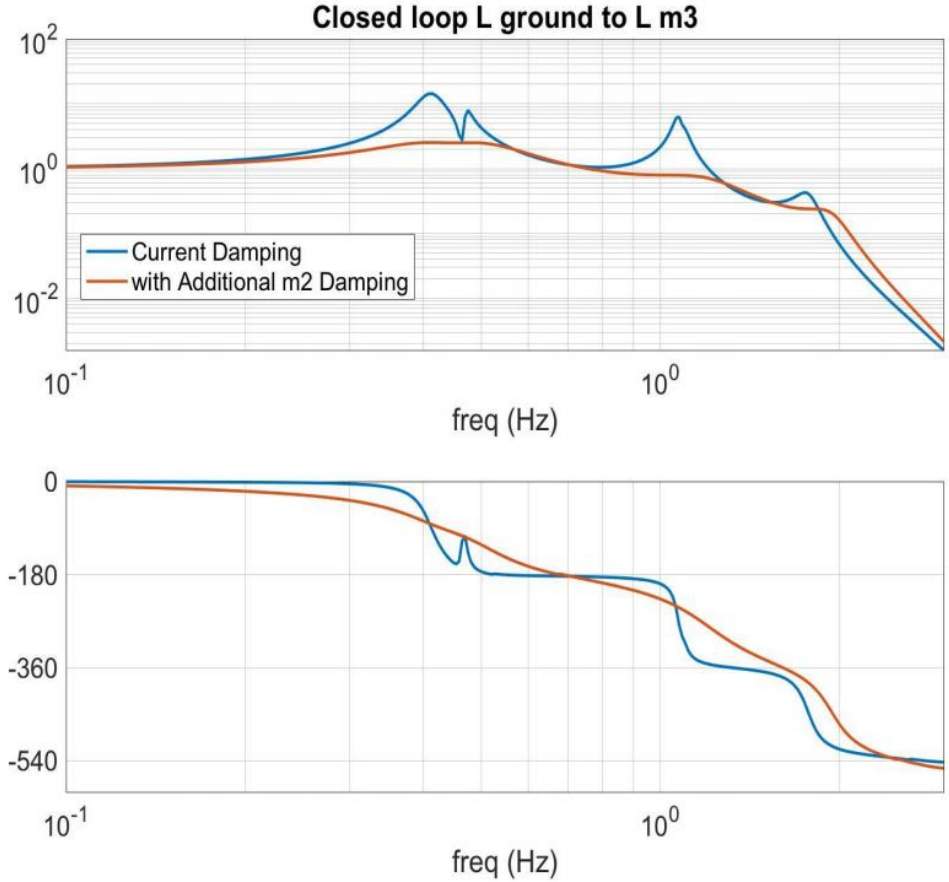
As a reminder…

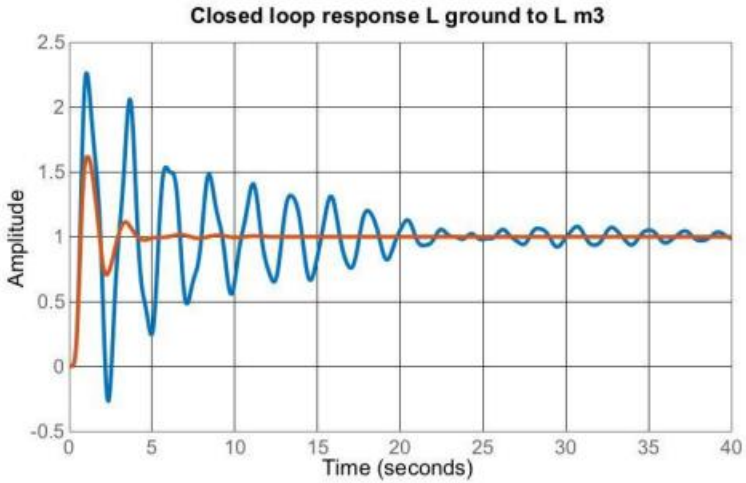
Displacement Sensor Sensitivity (In air, no isolation)



Cooper *et al* 2018 *Class. Quantum Grav.* 35 095007

Beamsplitter damping with interferometers



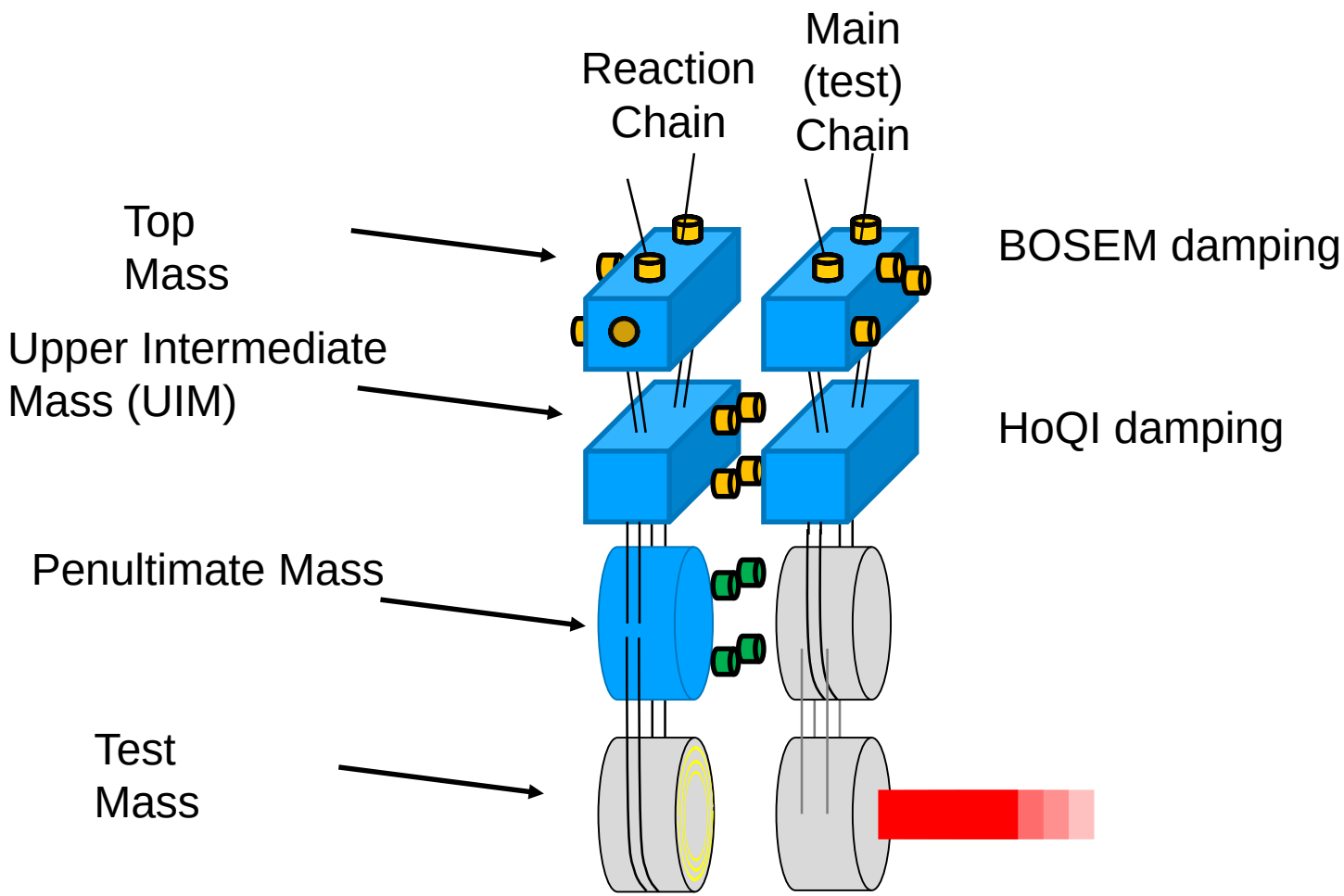


Use the beamsplitter model to compare with current damping

Adding HoQI at M2 (2nd stage) allows increased damping, reducing suspension resonances.

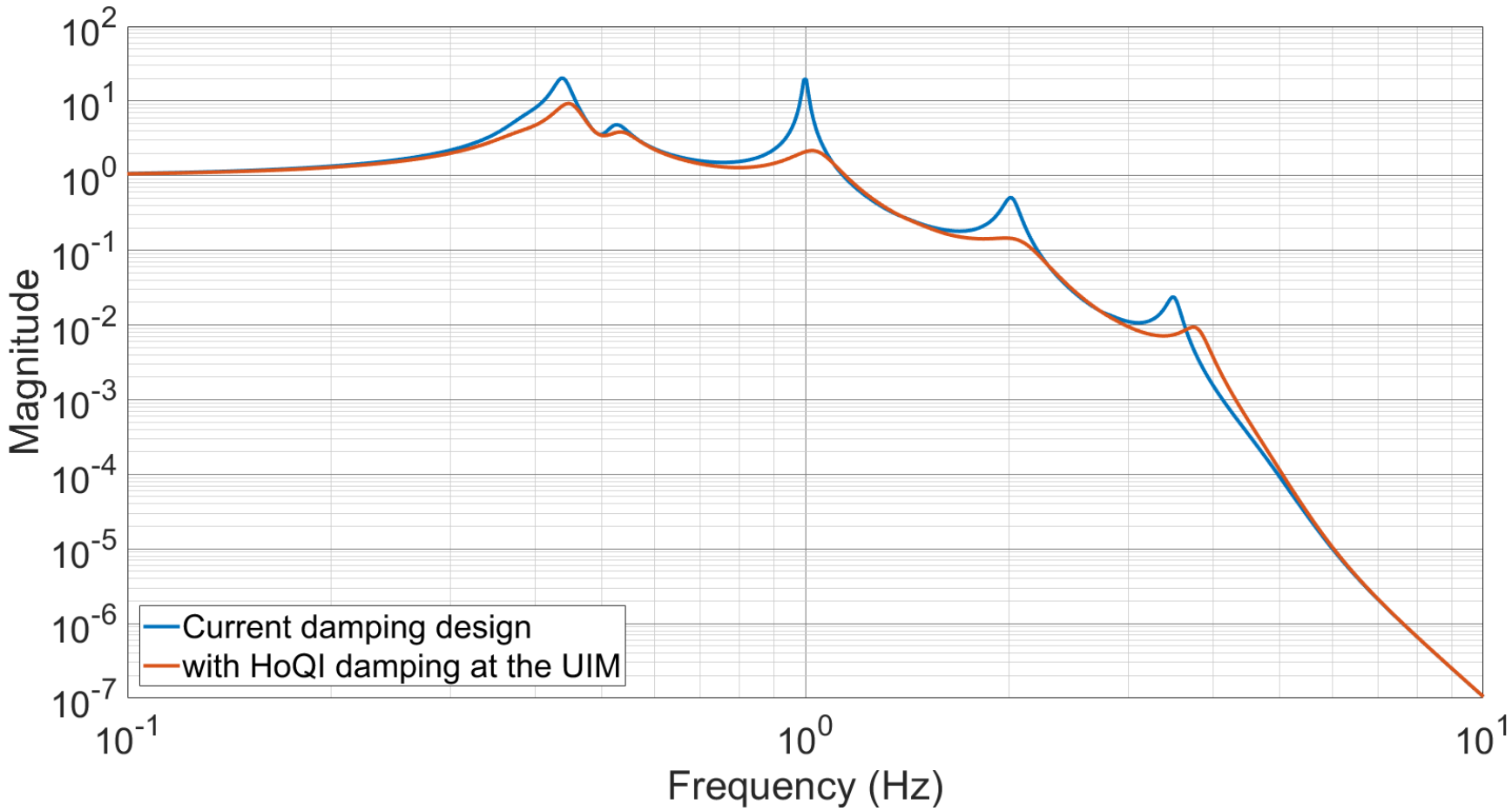
Plots by Leonid Prokhorov

Suspension Projection



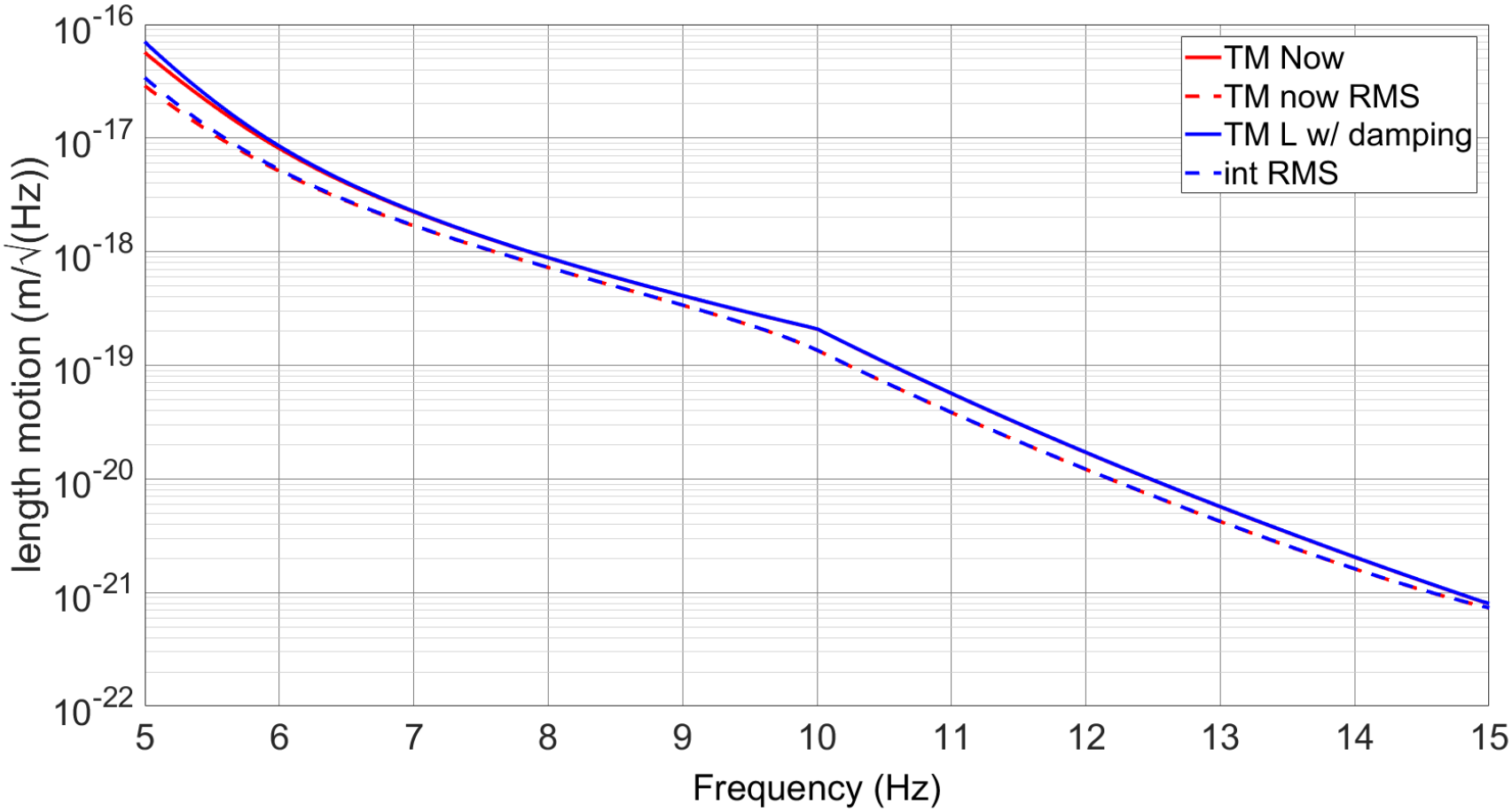
G1400964

Damping UIM with HoQI



Plot from Brian Lantz

HoQI UIM Damping Cont.



Plot from Brian Lantz

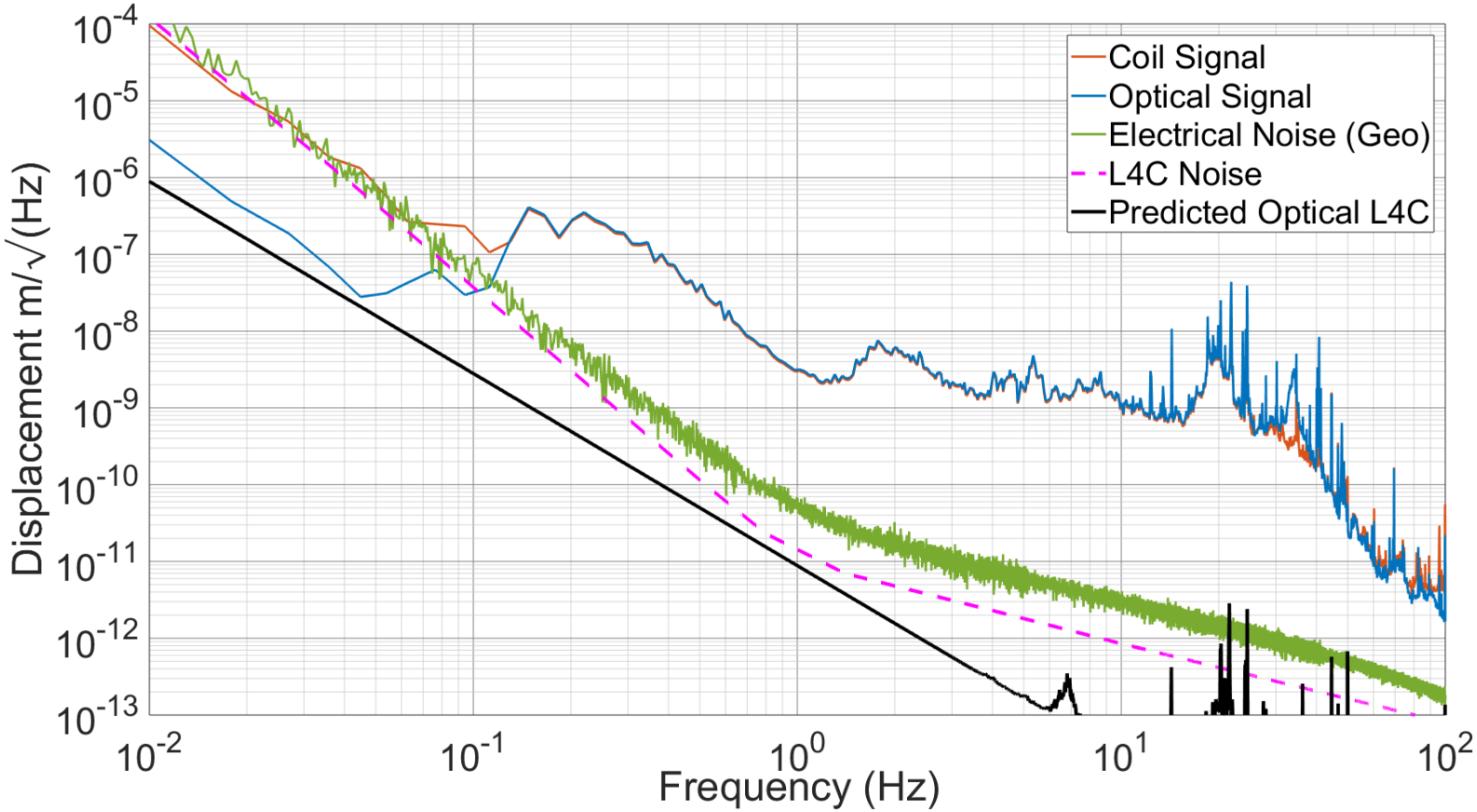
Breaking the seismic wall

We have developed a tool that can fix this in two ways

1) Local damping of suspensions

2) Reducing ISI motion with new sensors

Inertial Sensor Sensitivity (In air, no isolation)



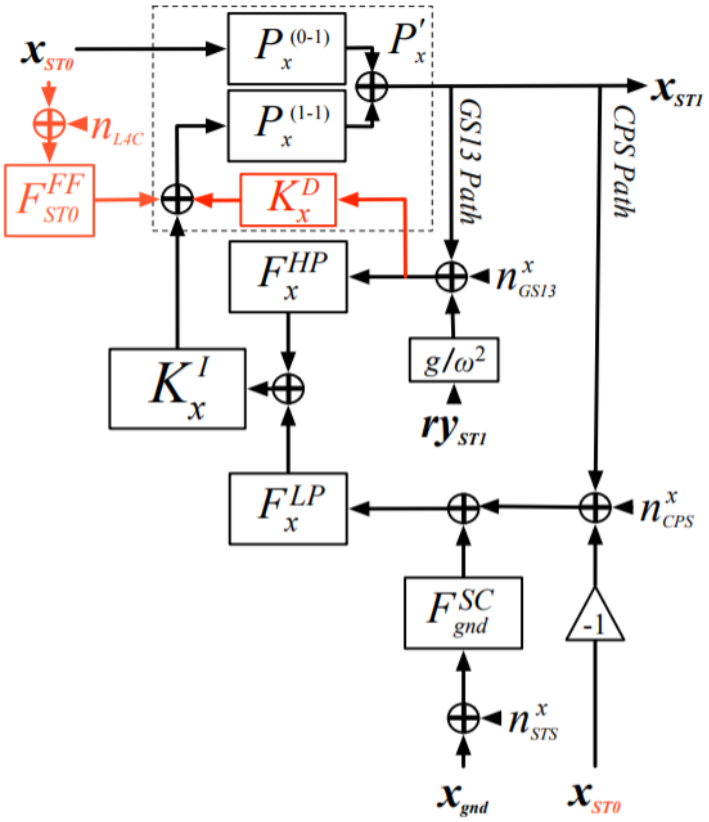
~ 100x higher resolution @10mHz than coil L4C

Ham ISI Model

Need to be able to quantify how much improvement new sensors, like the one's we're developing can improve the ISI performance.

We need to be able to add new filters to take advantage of new sensors

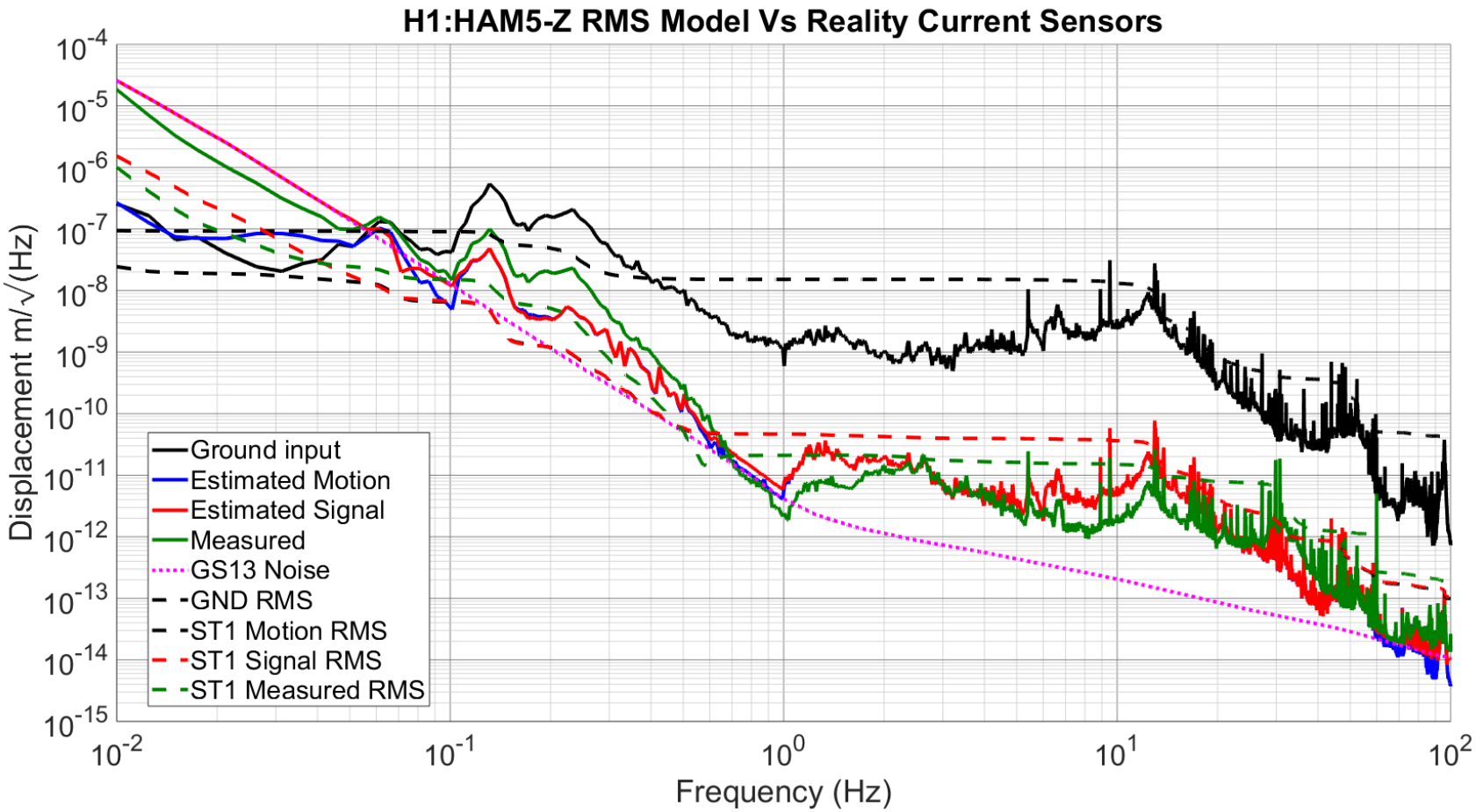
Useful to have a useable model to test different filters + filter design techniques and new sensors.



T1300645

See DCC: T1800092 for more details

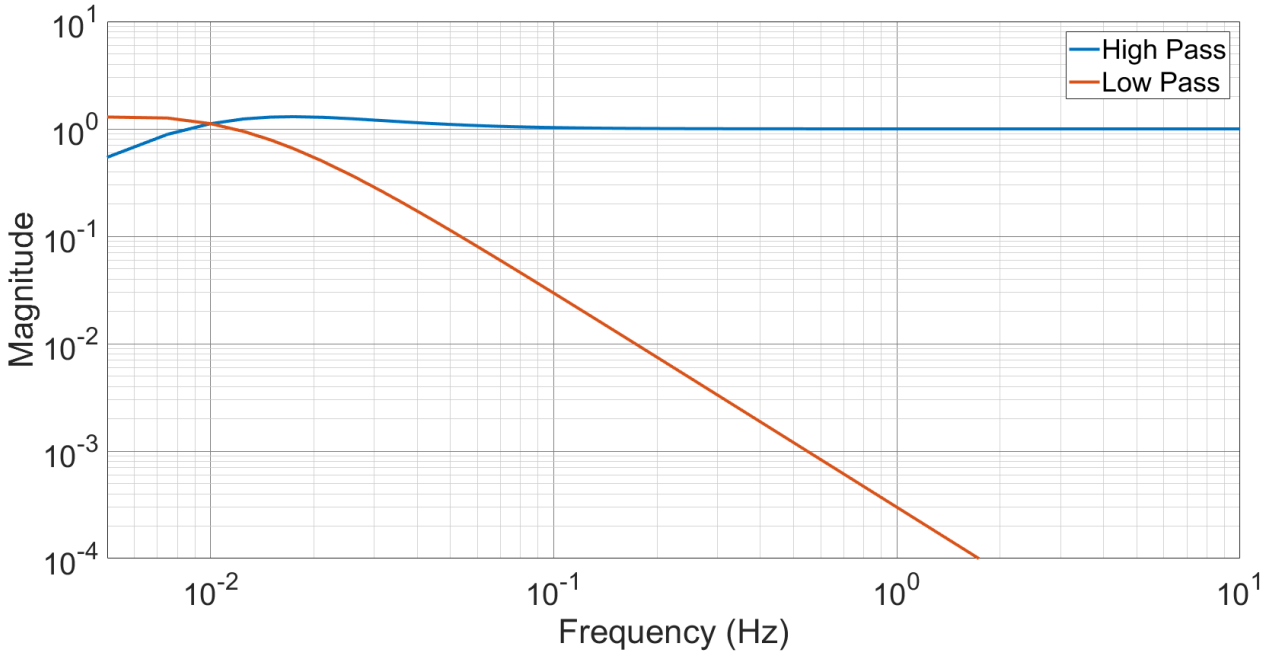
As a reminder - Model Performance



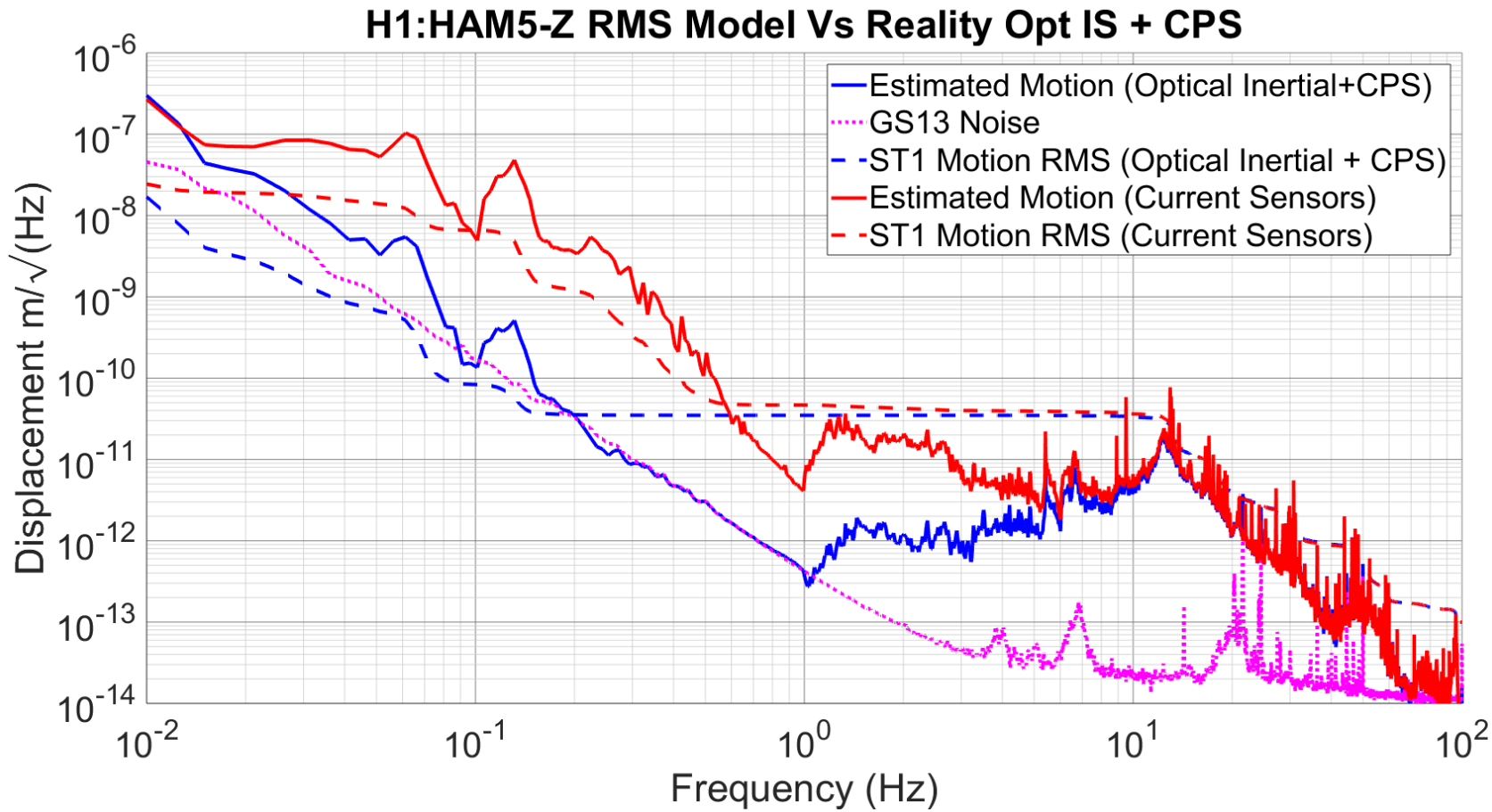
Blending filters

To get best idea of ISI performance with new sensors, need to design some new filters.

High and low pass filters designed looping over a range of different binomial filters(~1000), minimising the velocity RMS of the sensor noises.



HAM ISI: CPS + Optical Inertial



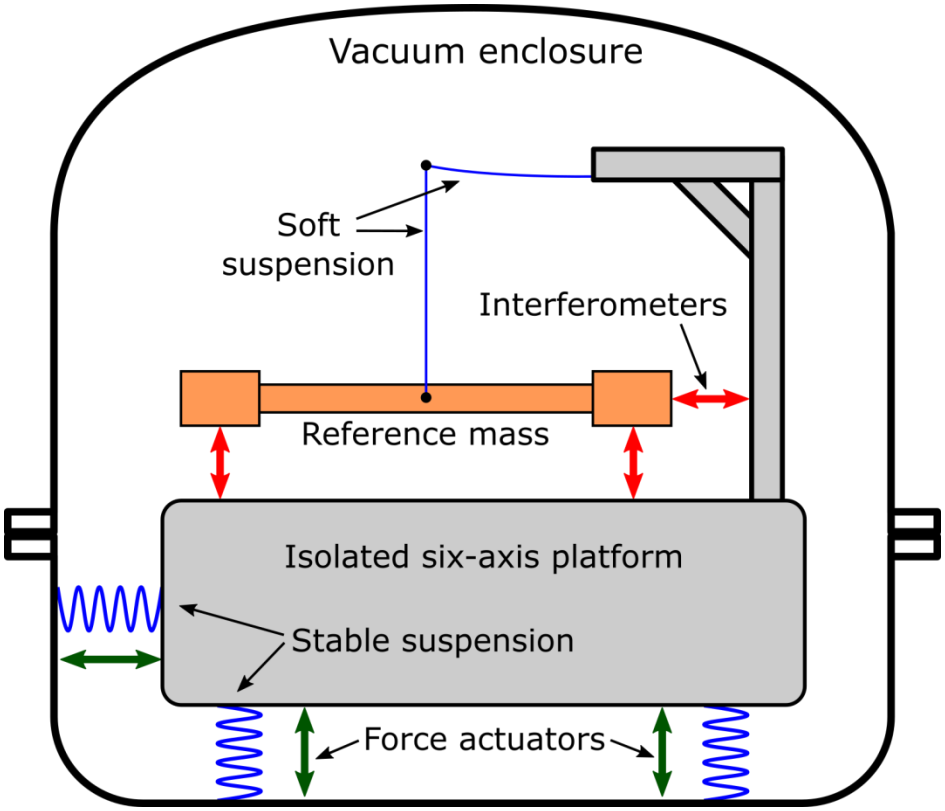
Looks good in Z but harder in translation…

6D Isolator Concept

If replacing the current sensors is not enough, need to change the dynamics.

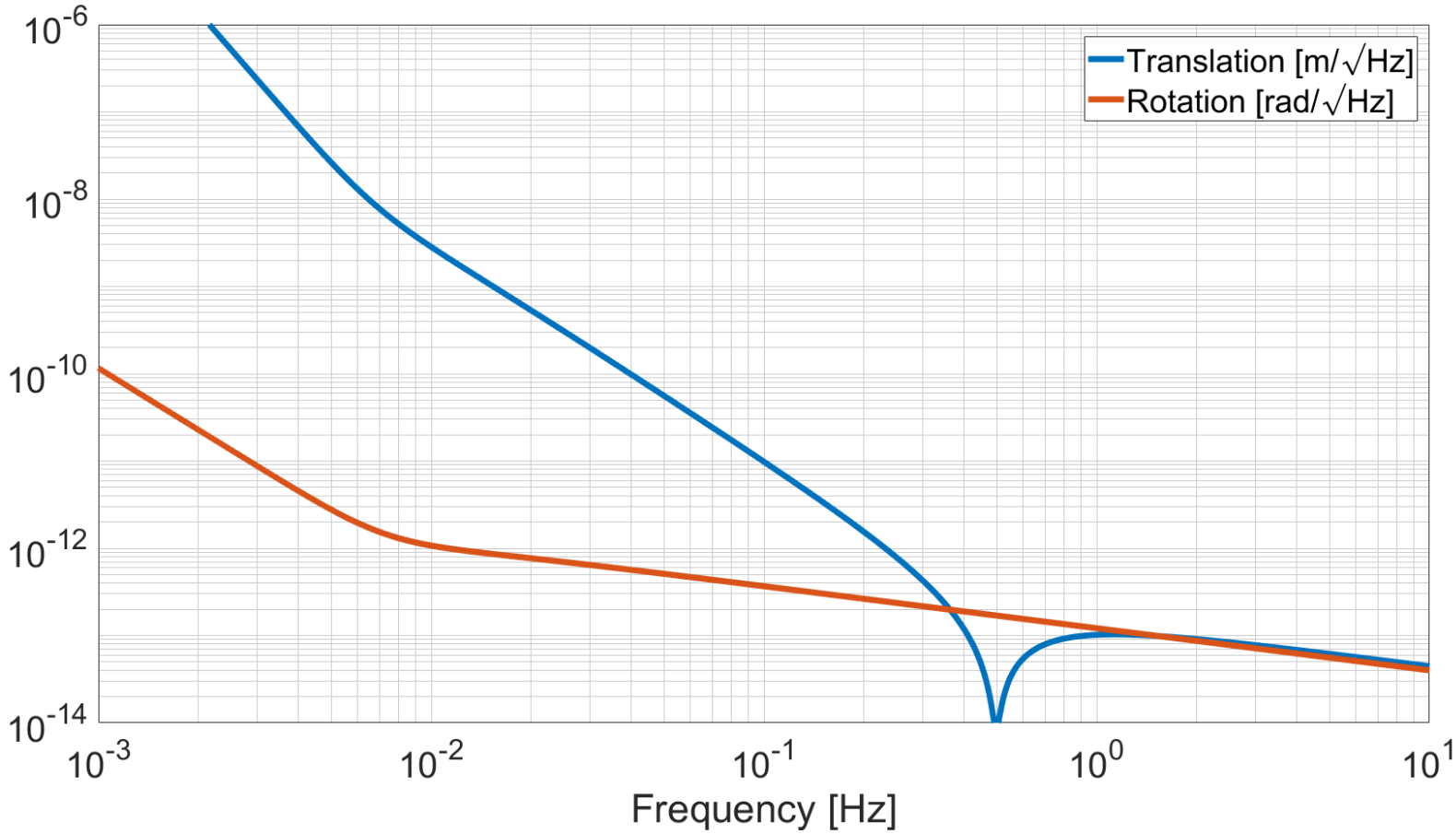
Developing a 6D isolator at Birmingham with low stiffness in all 6 DOFs.

Current Progress: Ordered vacuum chamber, design of ISI and control scheme is underway.



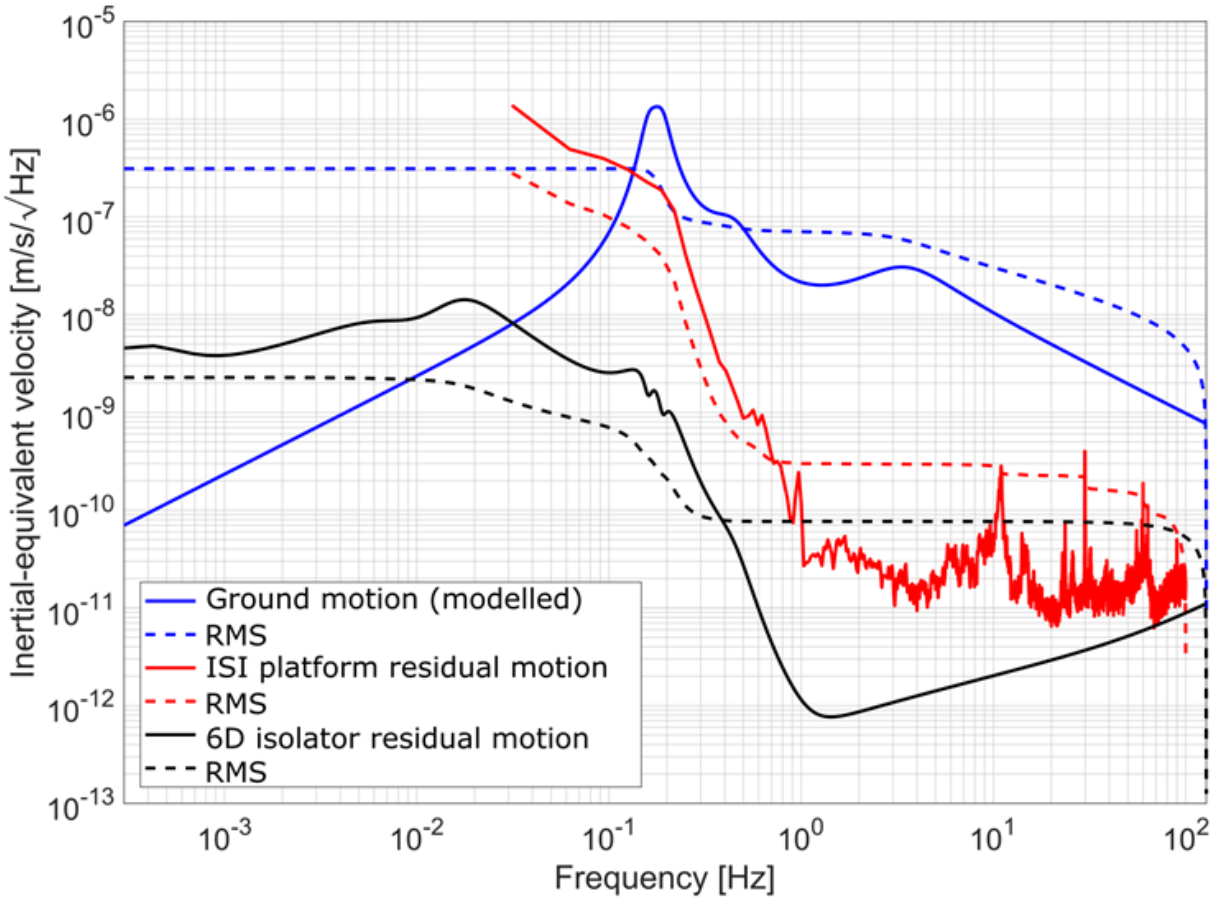
C.M. Mow-Lowry and D. Martynov
arXiv:1801.01468

6D Sensitivity



Plot by Amit Ubhi

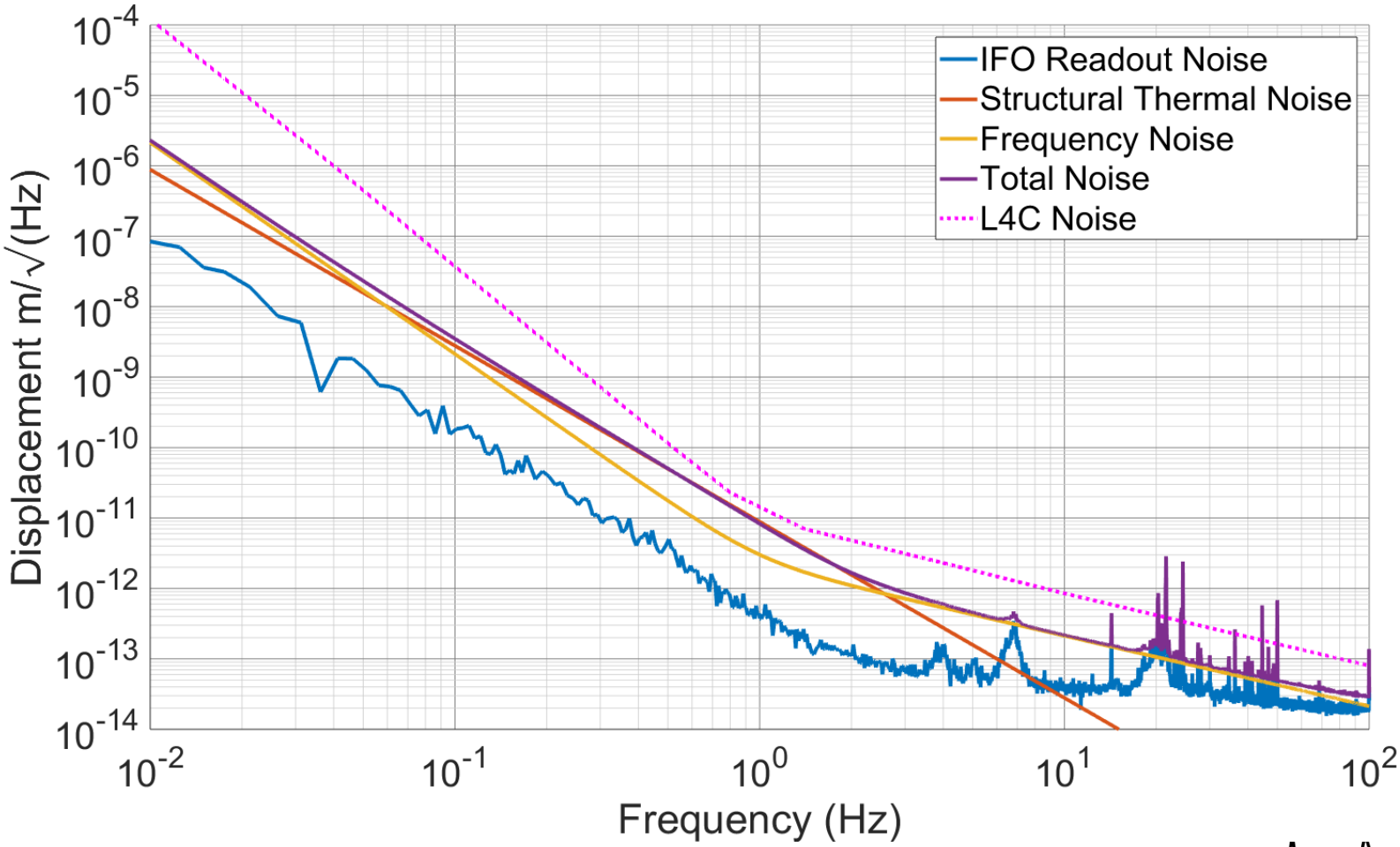
6D Performance



Plot by Conor Mow-Lowry

Extra slides

Optical inertial sensor noise budget



Loop structure

Model Features:

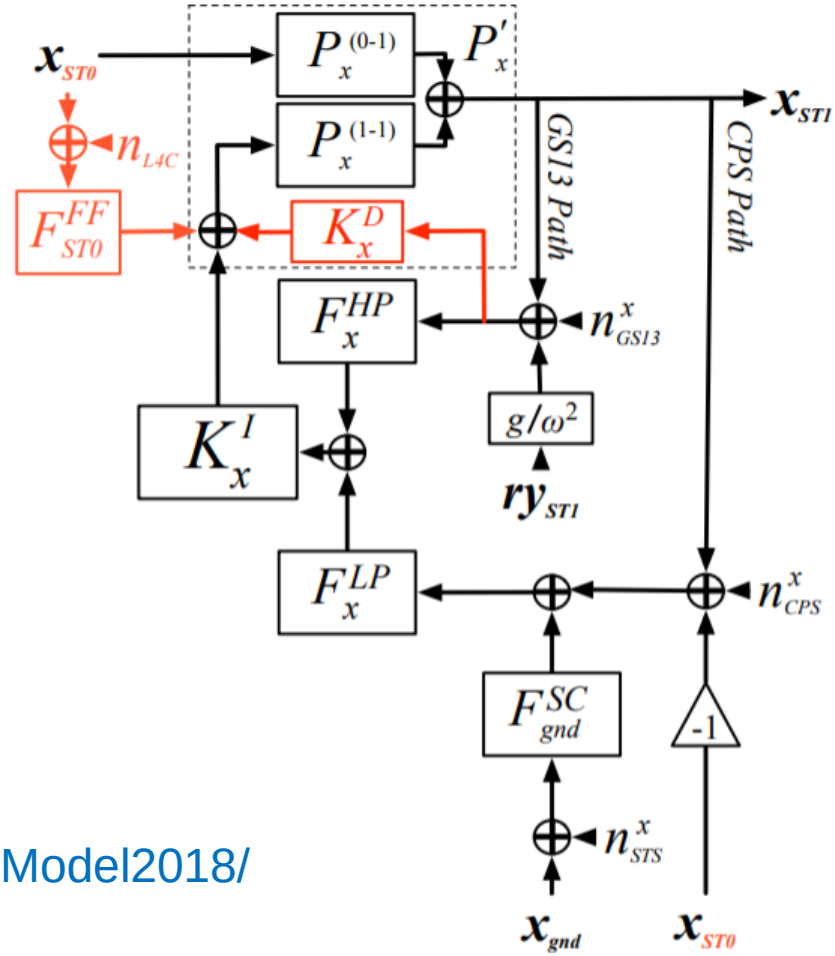
6 Degree of Freedom

Custom sensor noises

Custom filter support

Support for LHO and LLO*

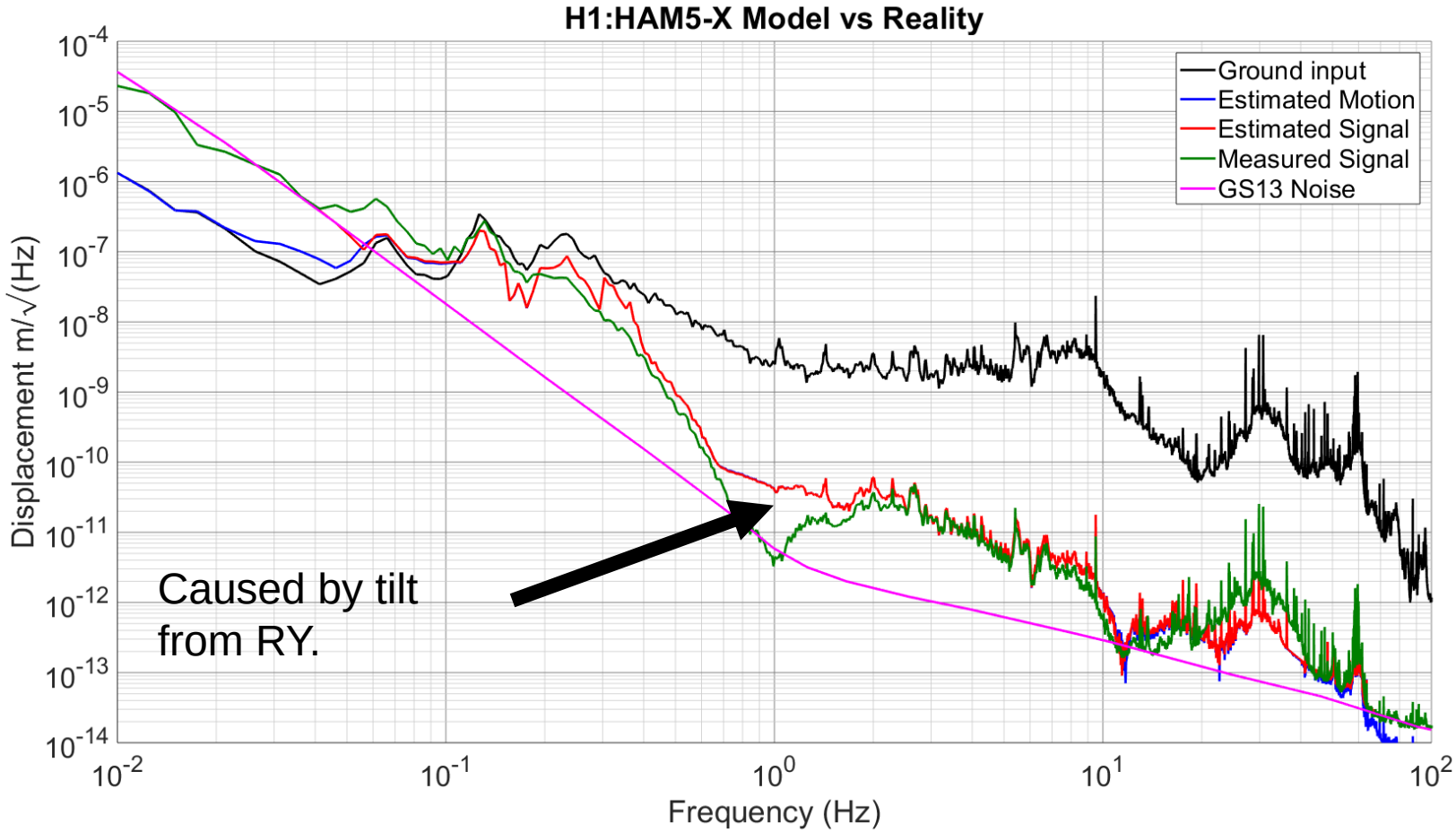
Can now calculate suspension point motion for use in suspension models



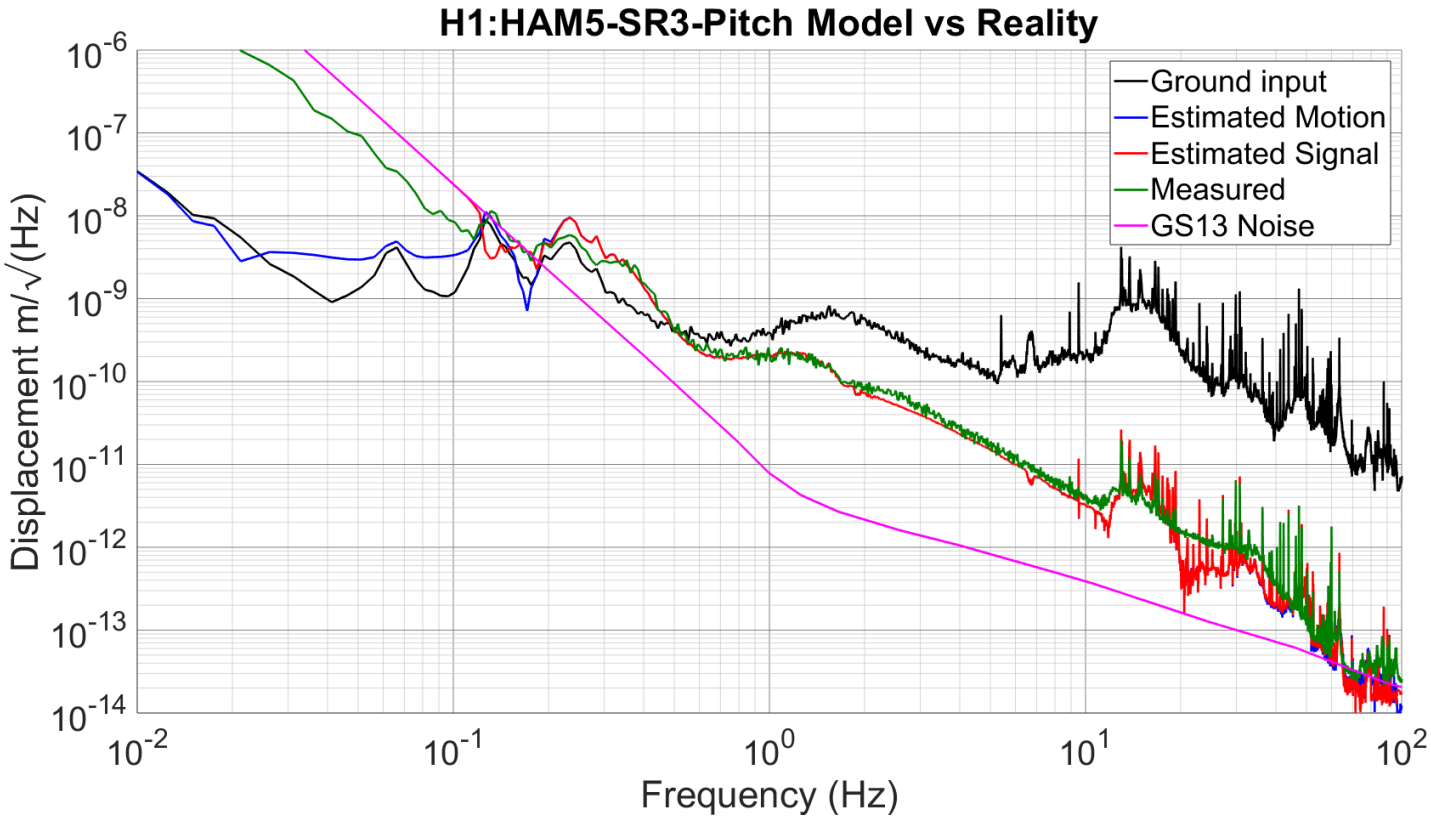
Available on SEI SVN at:

seiSVN/HAM-ISI/Common/hamISIModel2018/

Model Performance: SEI Coordinates



Model Performance: SUS Coordinates



Longitudinal, Transverse, Pitch, Roll work ‘well – similar agreement to above’
Yaw: some disagreement between 0.1 and 1Hz caused by RZ error
Vertical: Bad (Z,RX,RY contribute here – needs further investigation)