BSC HEPI Motion

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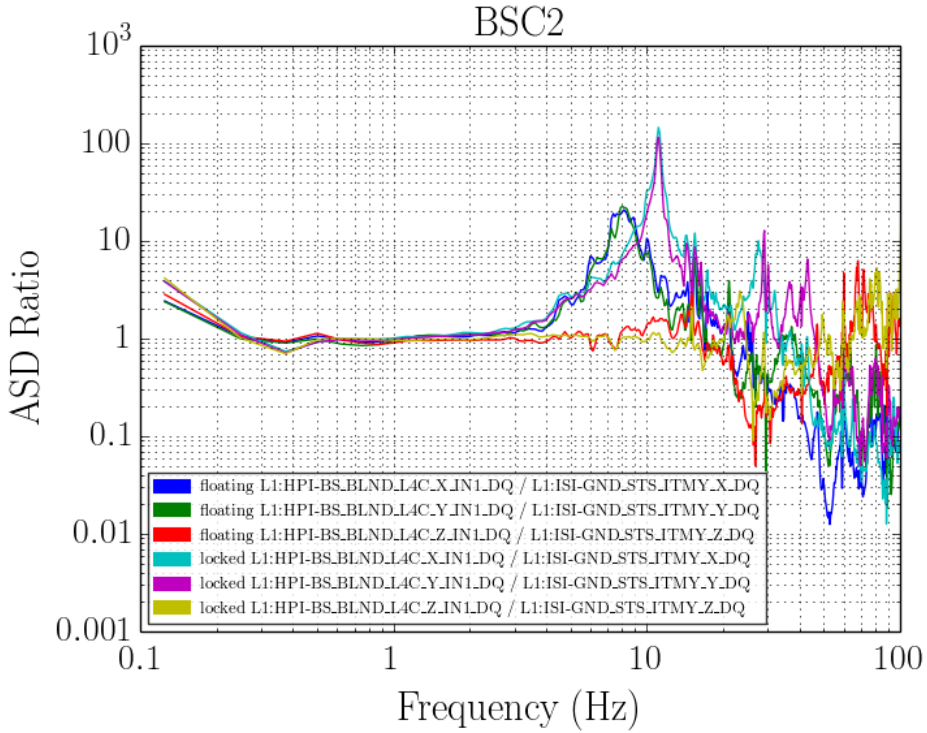
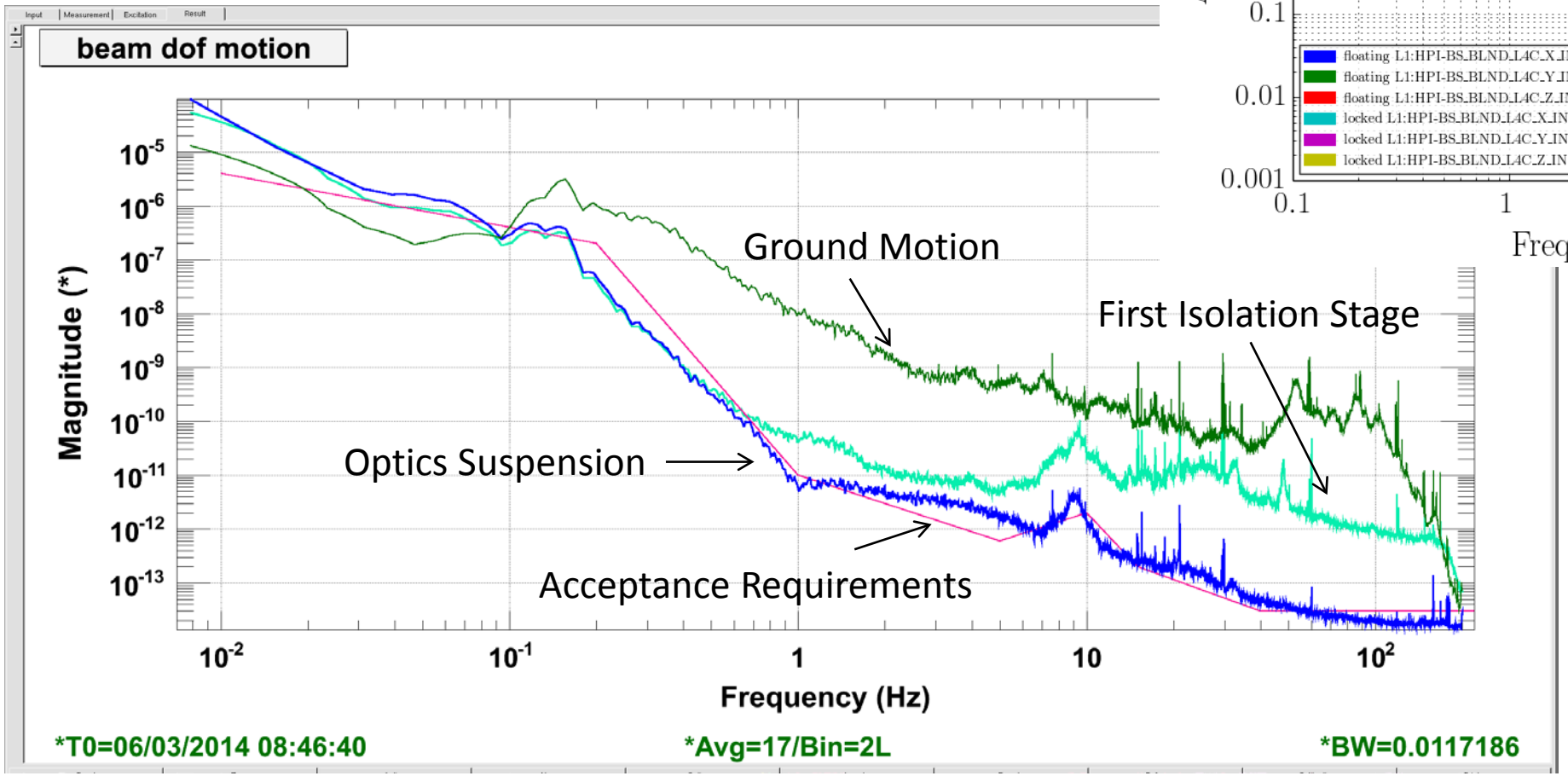
9/26/14

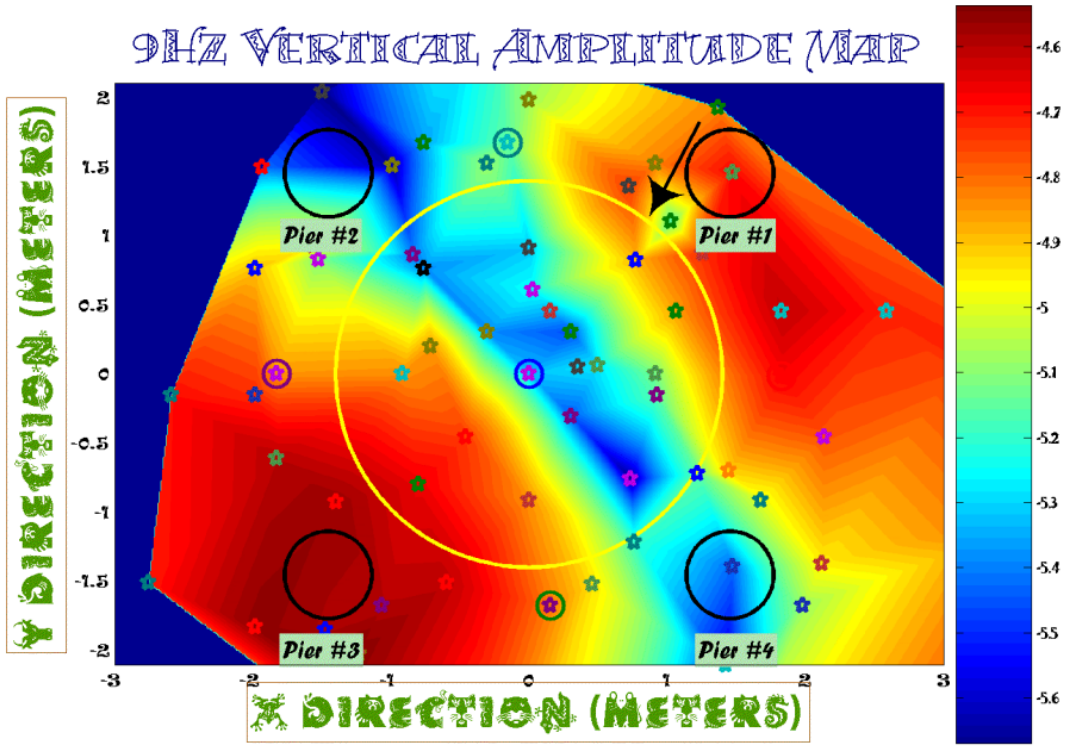
The Issue

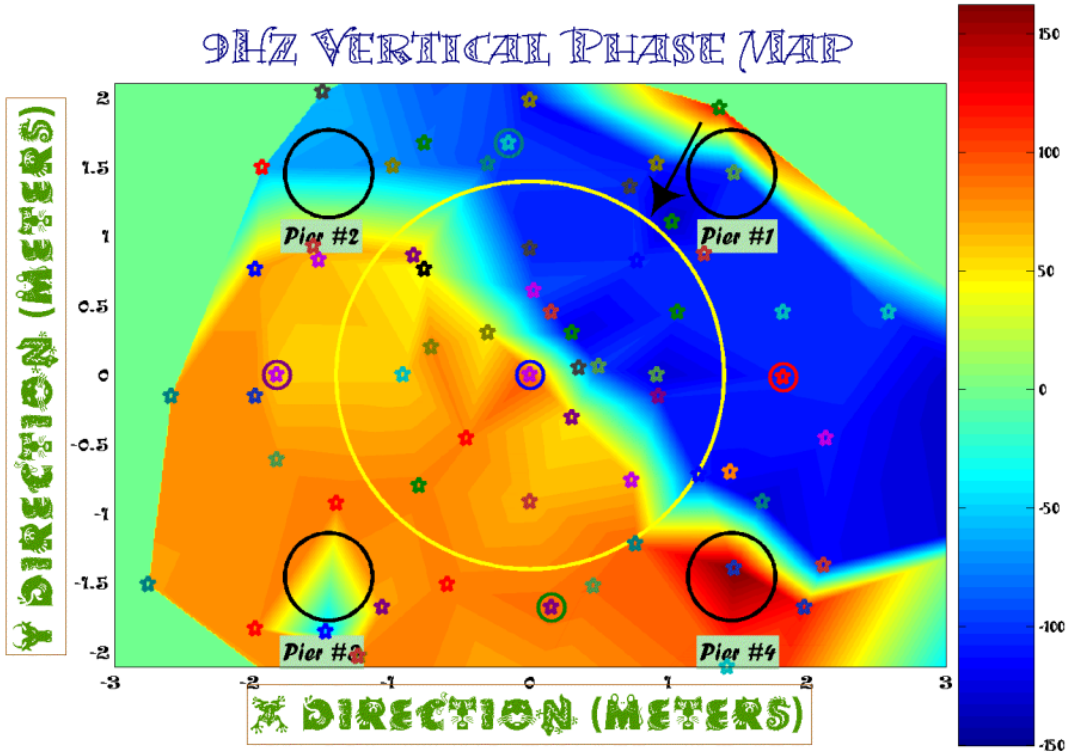

BSC2
ASD Ratio
Frequency (Hz)
floating L1:HPI-BS_BLND_L4C_X_IN1_DQ / L1:ISI-GND_STS_ITMY_X_DQ
floating L1:HPI-BS_BLND_L4C_Y_IN1_DQ / L1:ISI-GND_STS_ITMY_Y_DQ
floating L1:HPI-BS_BLND_L4C_Z_IN1_DQ / L1:ISI-GND_STS_ITMY_Z_DQ
locked L1:HPI-BS_BLND_L4C_X_IN1_DQ / L1:ISI-GND_STS_ITMY_X_DQ
locked L1:HPI-BS_BLND_L4C_Y_IN1_DQ / L1:ISI-GND_STS_ITMY_Y_DQ
locked L1:HPI-BS_BLND_L4C_Z_IN1_DQ / L1:ISI-GND_STS_ITMY_Z_DQ


beam dof motion
Magnitude (*)
Frequency (Hz)
Ground Motion
First Isolation Stage
Optics Suspension
Acceptance Requirements
*T0=06/03/2014 08:46:40
*Avg=17/Bin=2L
*BW=0.0117186

LASTI Result (2005)

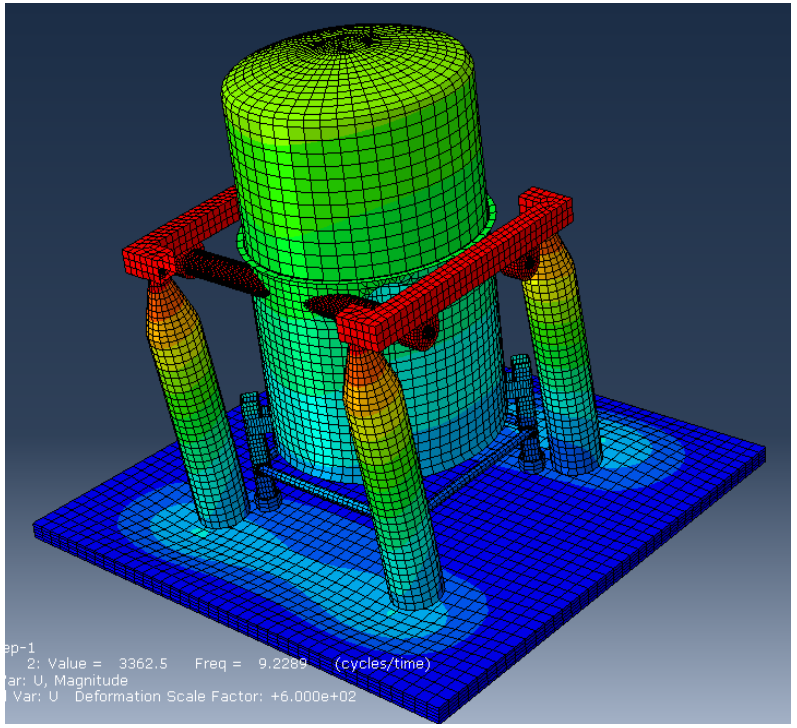
- LASTI measurements suggested floor motion was coupled with pier motion

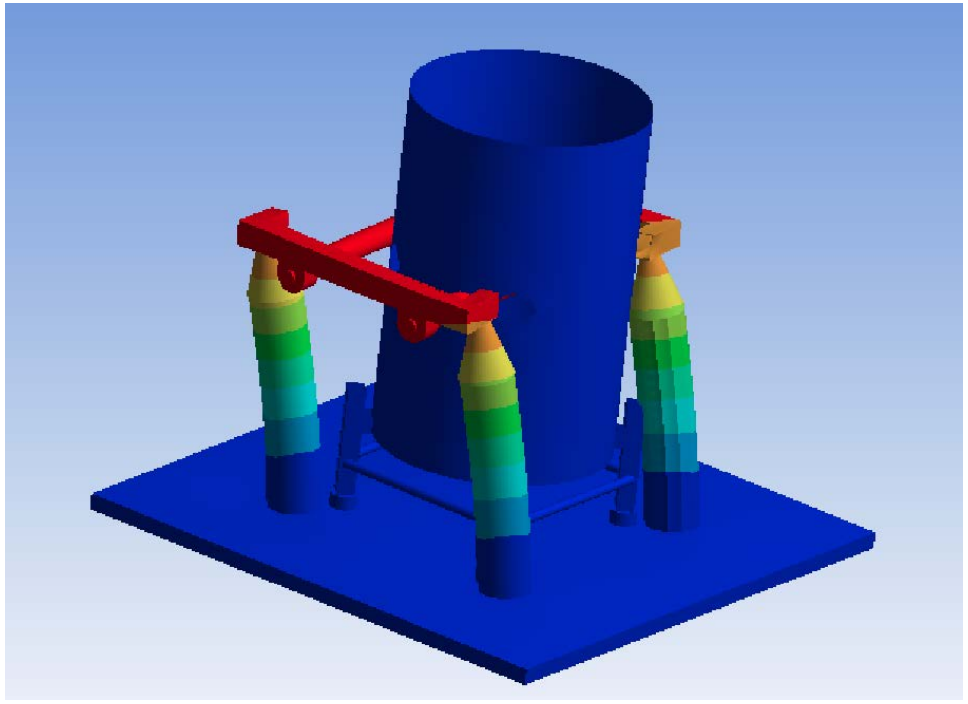




Modeling Efforts

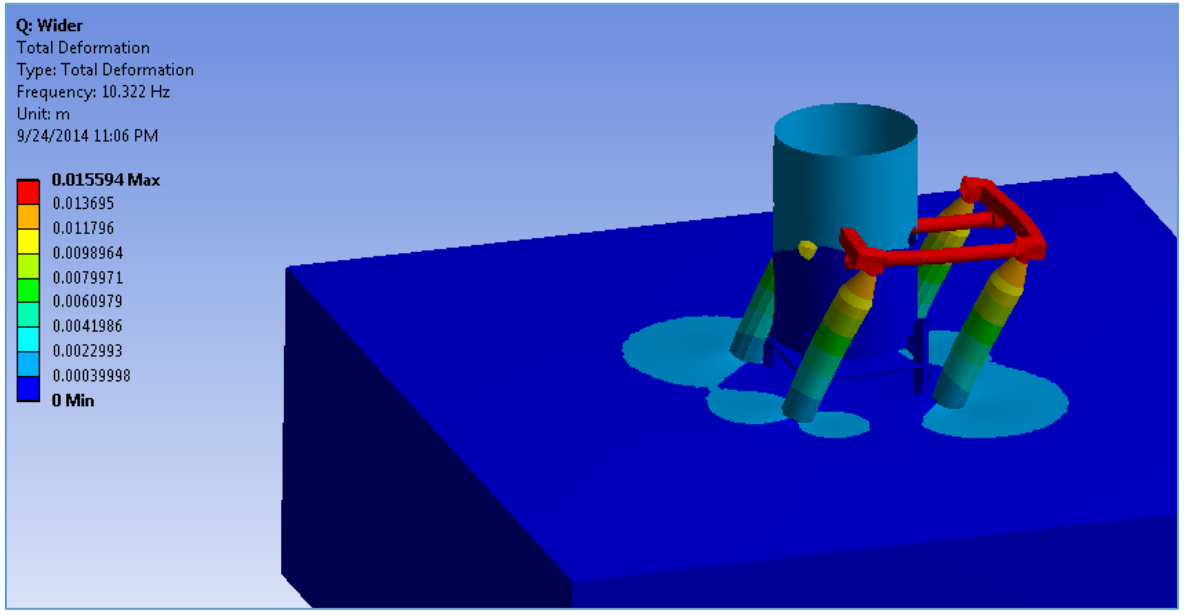
- Christophe at the University of Brussels (Abaqus)
- Stanford (ANSYS)

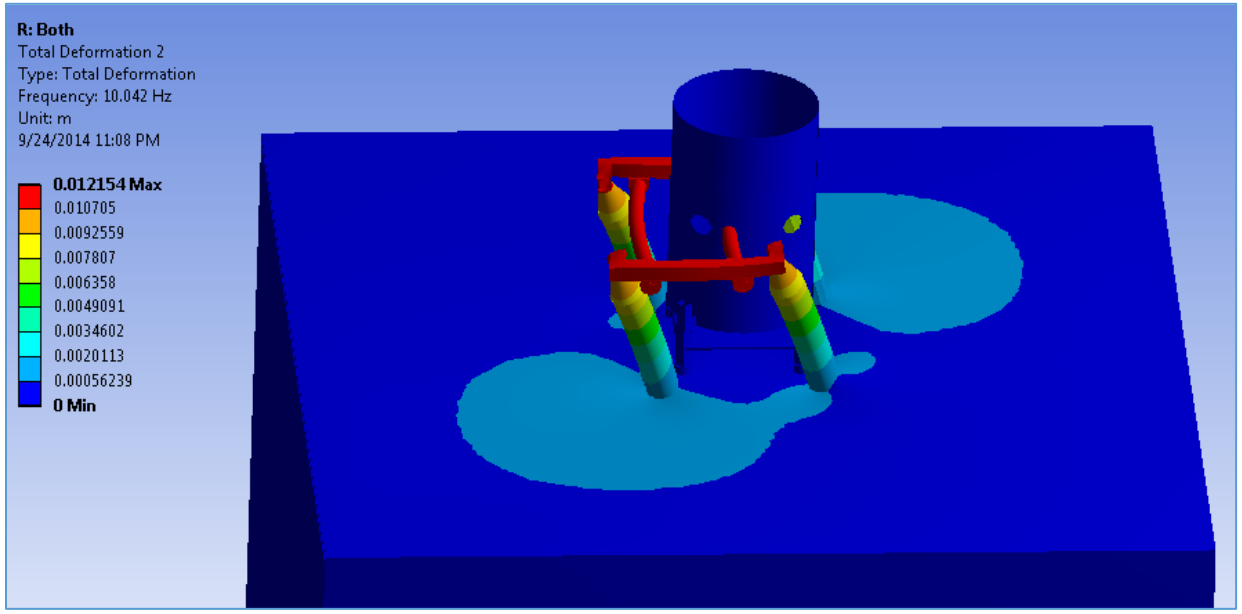




Modeling Results

- Models do not clearly agree with measurements or between models
- Variation of boundary conditions led to different results
- Unclear which BCs to use





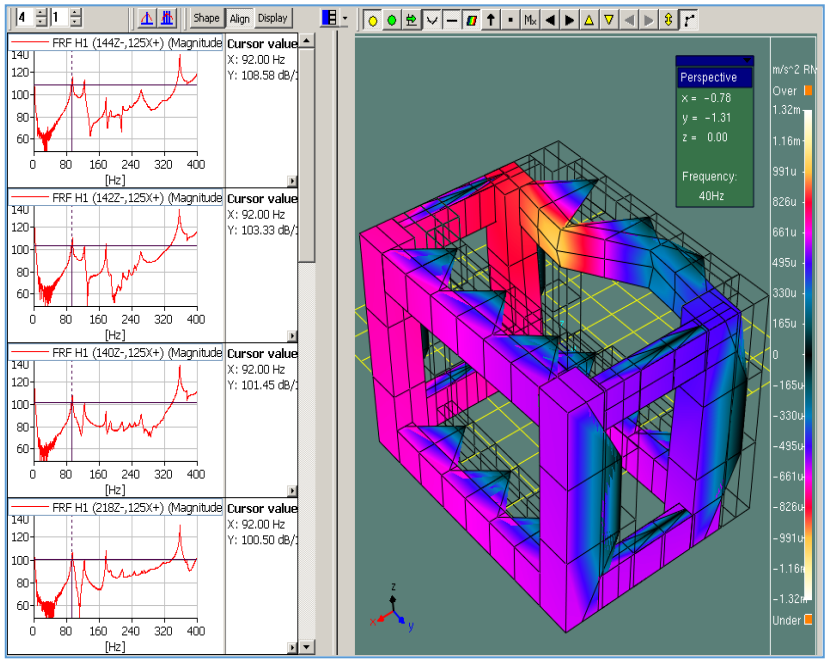
Real Information Needed

- Want specific mode shapes to determine how the floor and the rest of the structure is moving
- B&K system can be used for this function

Hardware Setup | Measurement Template: Modal

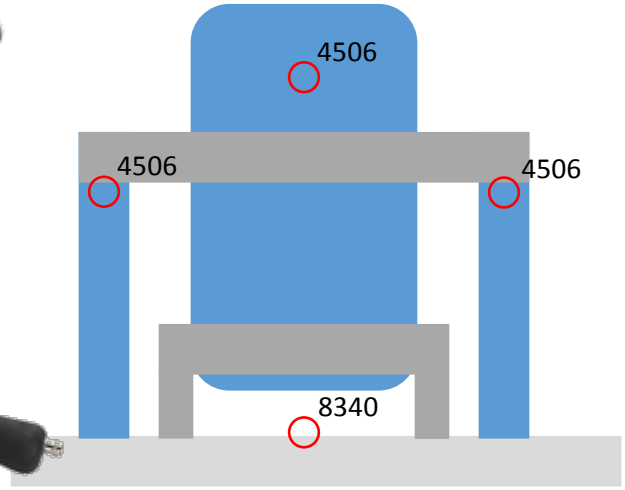
All | Aux | Basic | Calibration | Channel | Ext. Amp | Transducer | Vibration

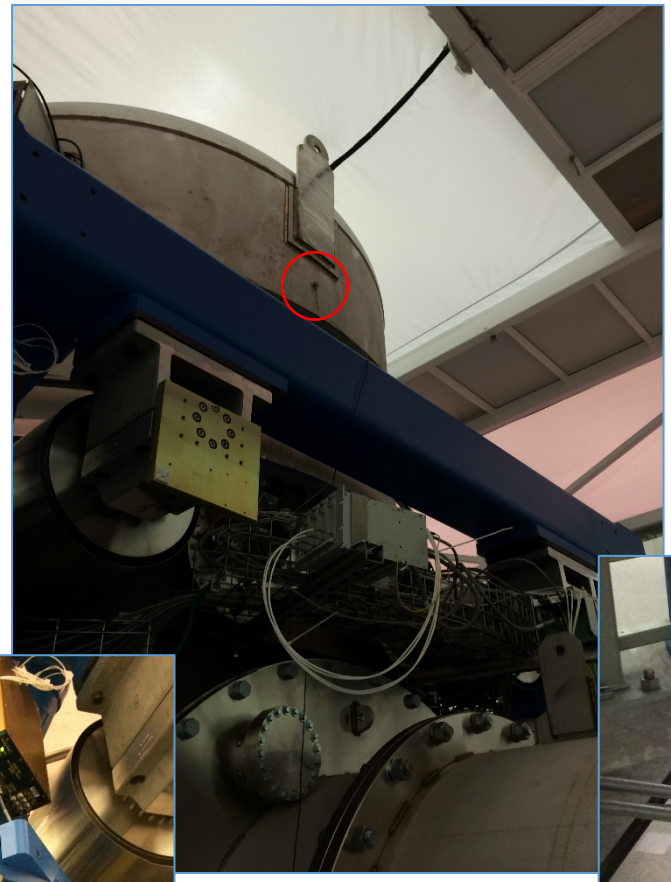
	Status	Frame	Module	Slot	Chn	Channel Type	Transducer Family	Transducer Type	Transducer Serial Number	Transducer Name	Transducer Description	Transducer Nom. Sensitivity	Use External Amplifier	External Amplifier Gain	TEDS Information	Calibration Time	Accredited Calib. Sensitivity	Use Transducer Data
Filter																		
1.1.1			3050-B-0	1	1	Input	Accelerometer	4506 Bx	30740	4506 Bx	DeltaTron	10m V/ms⁻²	☐	1 V/V	<Manufactu	12/4/2008	9.72m	☑
1.1.2			3050-B-0	1	2	Input	Accelerometer	4506 Bz	30740	4506 Bz	DeltaTron	10m V/ms⁻²	☐	1 V/V	<Manufactu	12/4/2008	9.971m	☑
1.1.3			3050-B-0	1	3	Input	Accelerometer	4506 By	30740	4506 By	DeltaTron	10m V/ms⁻²	☐	1 V/V	<Manufactu	12/4/2008	9.882m	☑
1.1.4			3050-B-0	1	4	Input							☐					☐
1.1.5			3050-B-0	1	5	Input							☐					☐
1.1.6			3050-B-0	1	6	Input							☐					☐
1.2.1			3050-B-0	2	1	Input	Accelerometer	4506 Bx	30698	4506 Bx	DeltaTron	10m V/ms⁻²	☐	1 V/V	<Manufactu	1/7/2009	9.703m	☑
1.2.2			3050-B-0	2	2	Input	Accelerometer	4506 By	30698	4506 By	DeltaTron	10m V/ms⁻²	☐	1 V/V	<Manufactu	1/7/2009	9.015m	☑
1.2.3			3050-B-0	2	3	Input	Accelerometer	4506 Bz	30698	4506 Bz	DeltaTron	10m V/ms⁻²	☐	1 V/V	<Manufactu	1/7/2009	10.13m	☑
1.2.4			3050-B-0	2	4	Input							☐					☐
1.2.5			3050-B-0	2	5	Input							☐					☐
1.2.6			3050-B-0	2	6	Input							☐					☐
1.3.1			3160-B-0	3	1	Input	Force	8207		8207	Hammer	227u V/N	☐	1 V/V			227u V/N	☑
1.3.2			3160-B-0	3	2	Input							☐					☐
1.3.3			3160-B-0	3	3	Input							☐					☐
1.3.4			3160-B-0	3	4	Input							☐					☐



B&K Setup at LHO

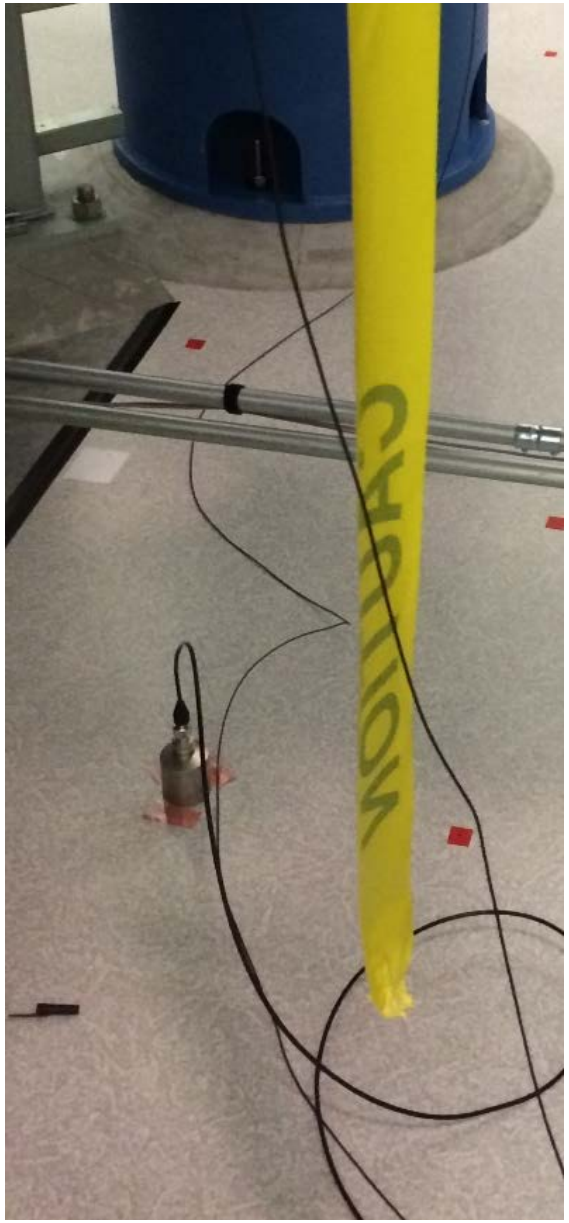
- Three 4506 accelerometers
- One 8340 accelerometers (the big one)
- 8208 Impact hammer (3 lb)
- 8206 Impact hammer





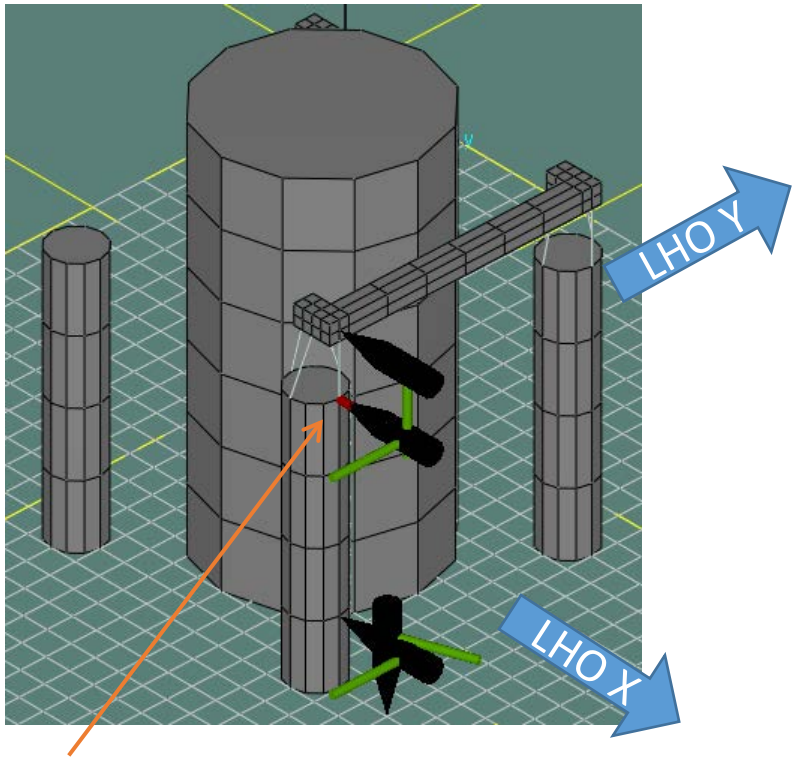
Initial Measurements

- Hammer hits on the floor and pier
- Nothing seen near 8 Hz
- Low coherence on 4506s
- Moved 8340 to pier, still nothing

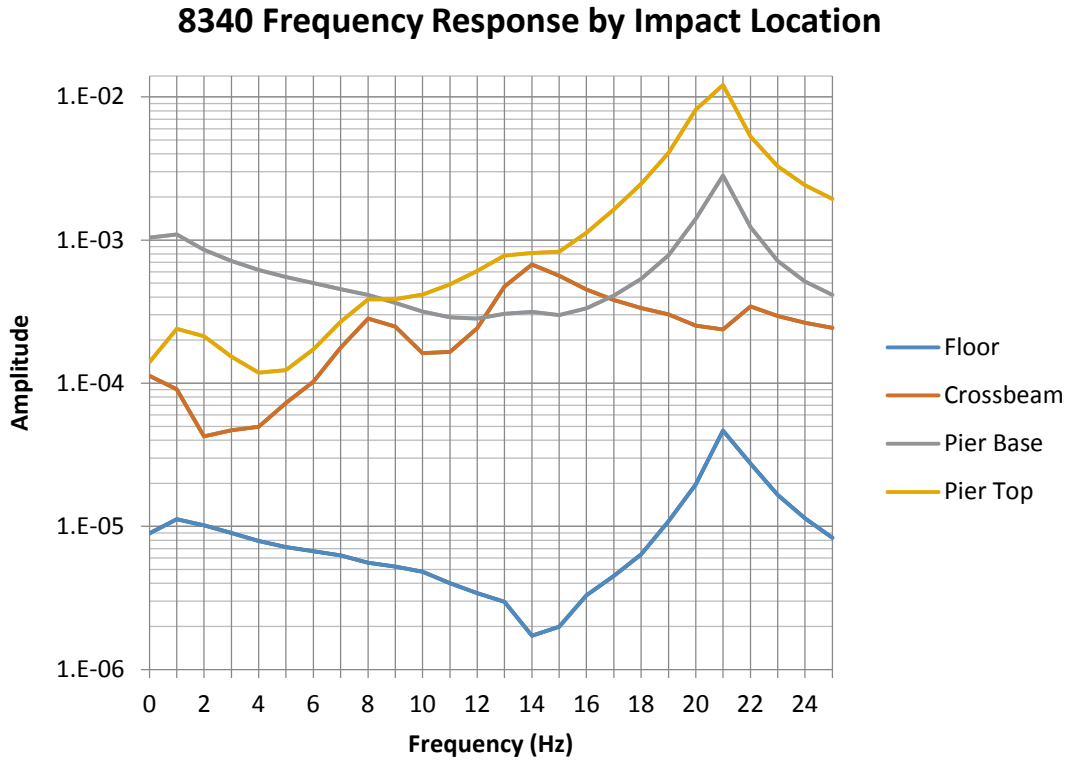


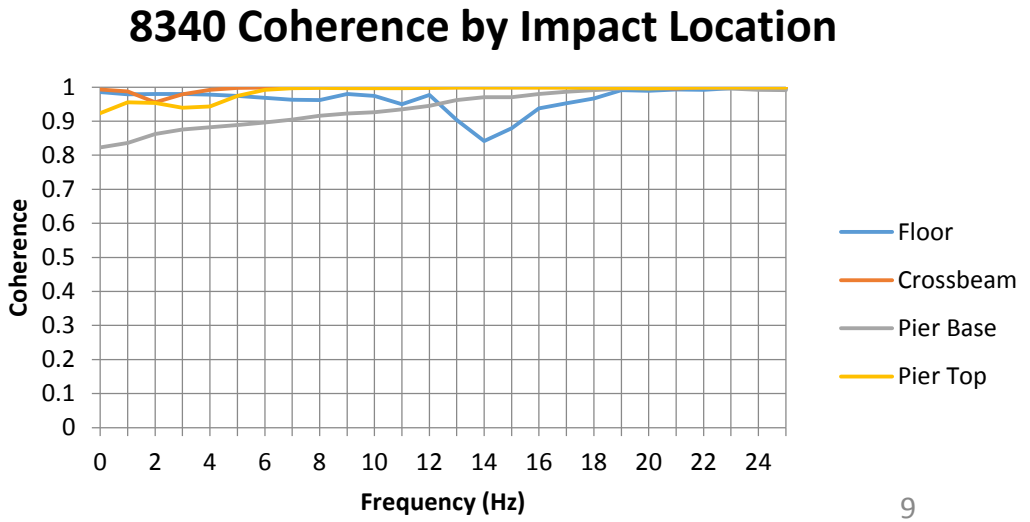
Initial Measurements

- Check L4C data and location
- L4C location in foot had not been hit
- Tried an impact on the crossbeam



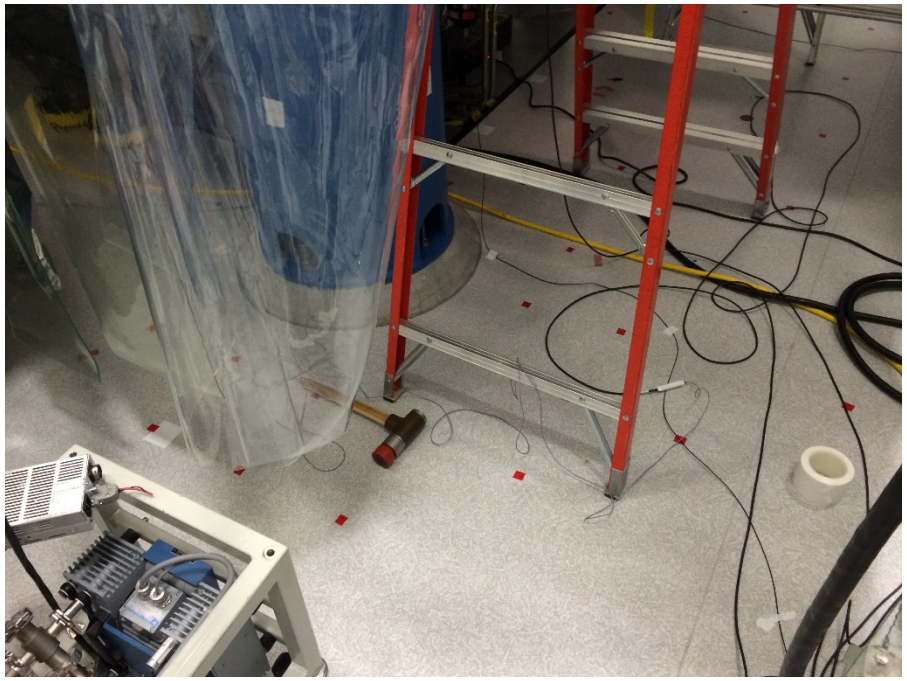
8340 Location





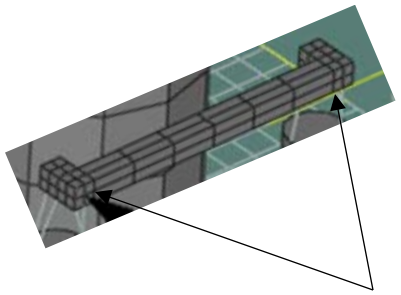
Full Floor System Measurement

- Created hit pattern up and around BSC
- Included the crossbeam

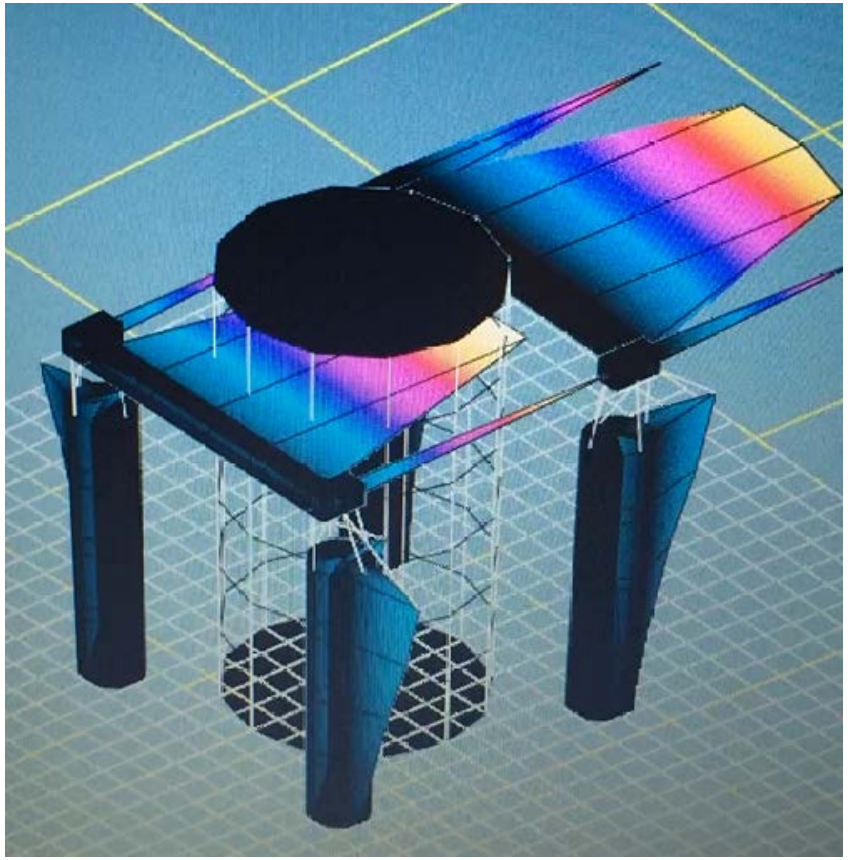


Full System Results

- Motion in crossbeam roughly 2-3x pier motion
- Almost no motion visible in the floor
- Crossbeam does not appear to bend

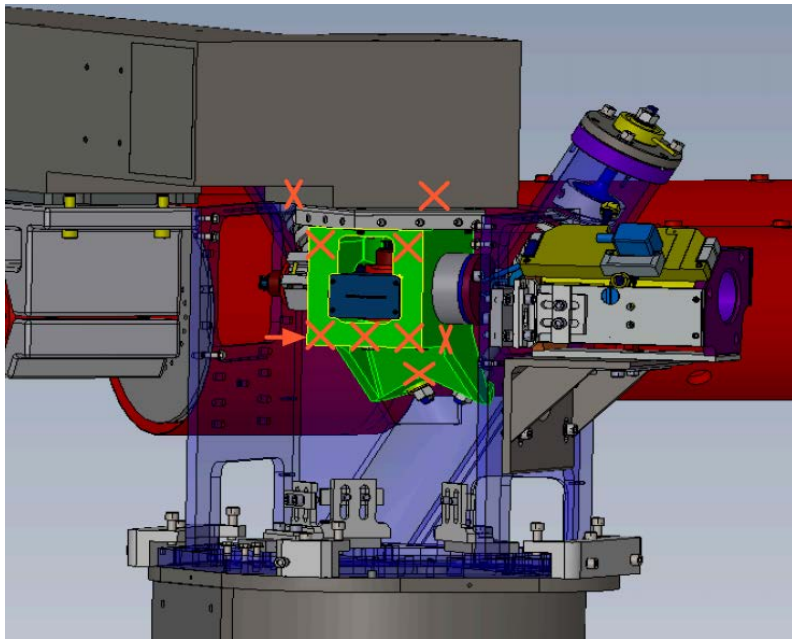


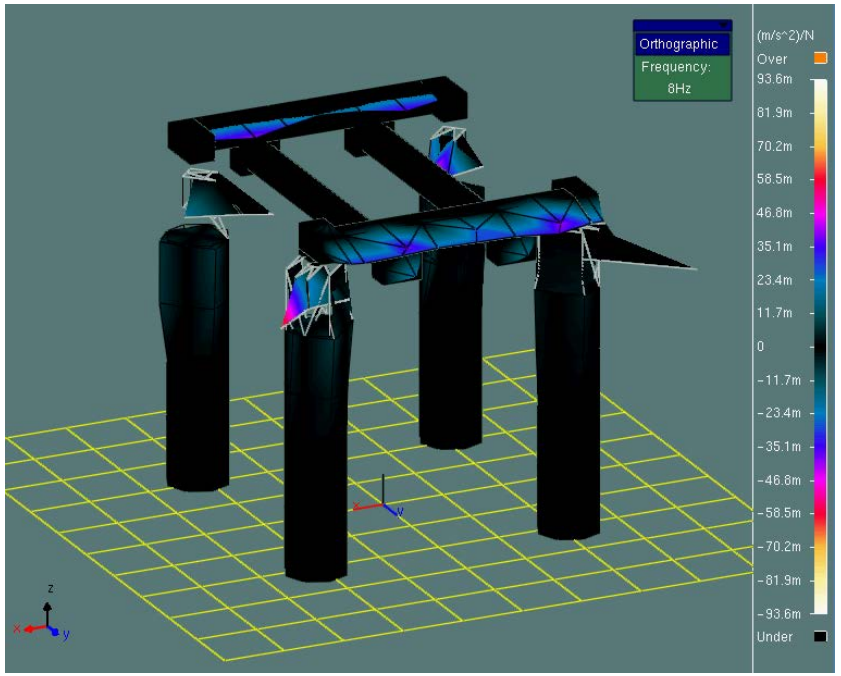
Lack of impact at these points creates illusion of bending. Motion only appears at impact points.



Measurements including HEPI

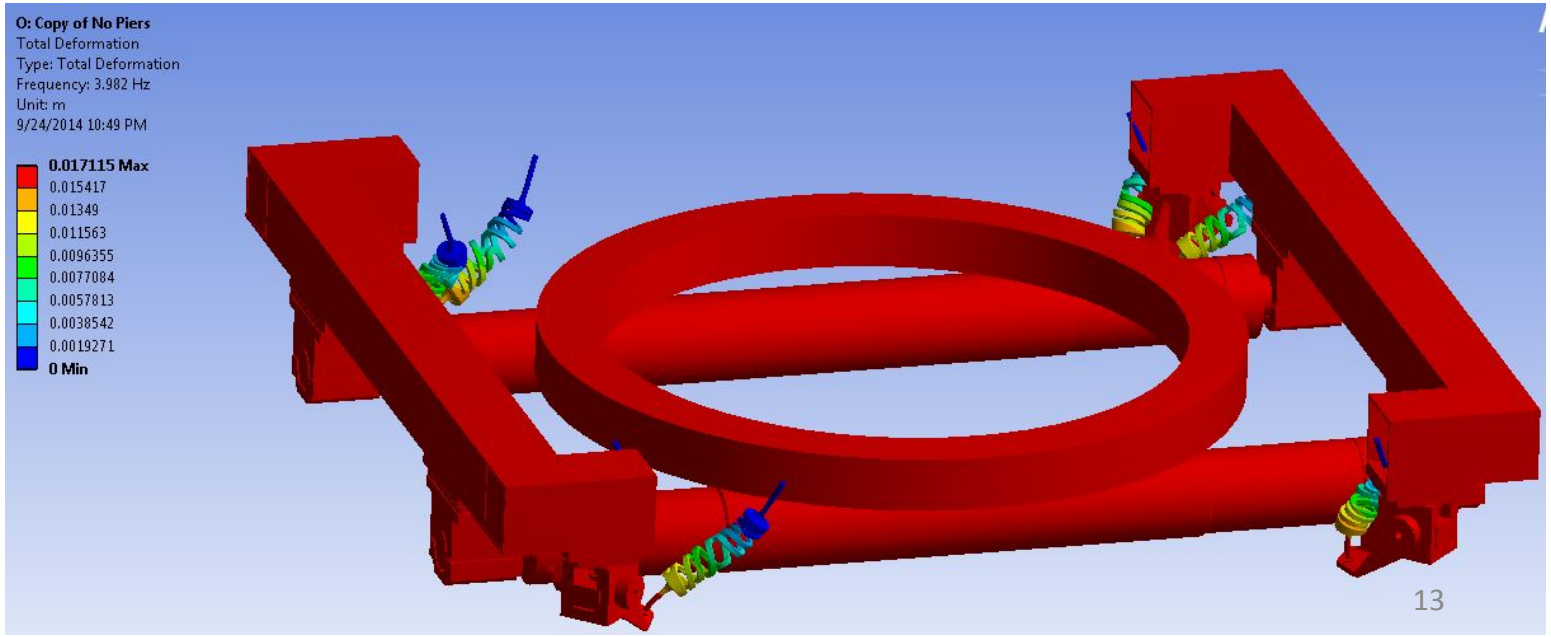
- New sequence including the HEPI actuator system
- Large motion seen with the foot, about twice the crossbeam
- Odd in that it only appears at the low point of the foot





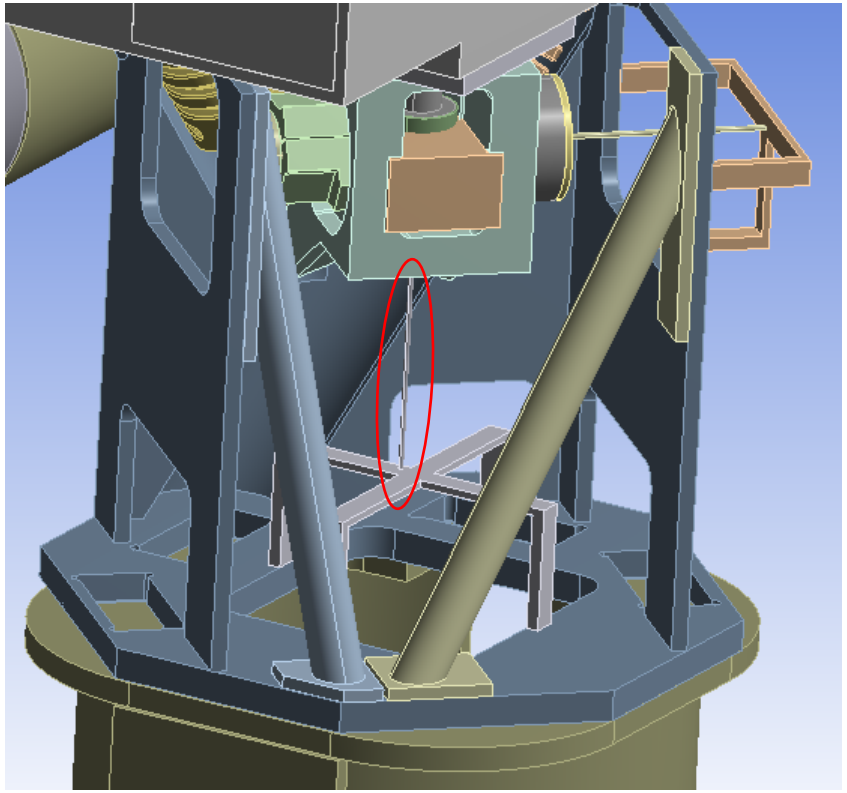
New Modeling at Stanford

- Now that we believe the HEPI system is the source of the issue, see if we can properly model it
- Initial modeling did not include the pier or actuators
- Odd motion not visible, frequency of 4 Hz

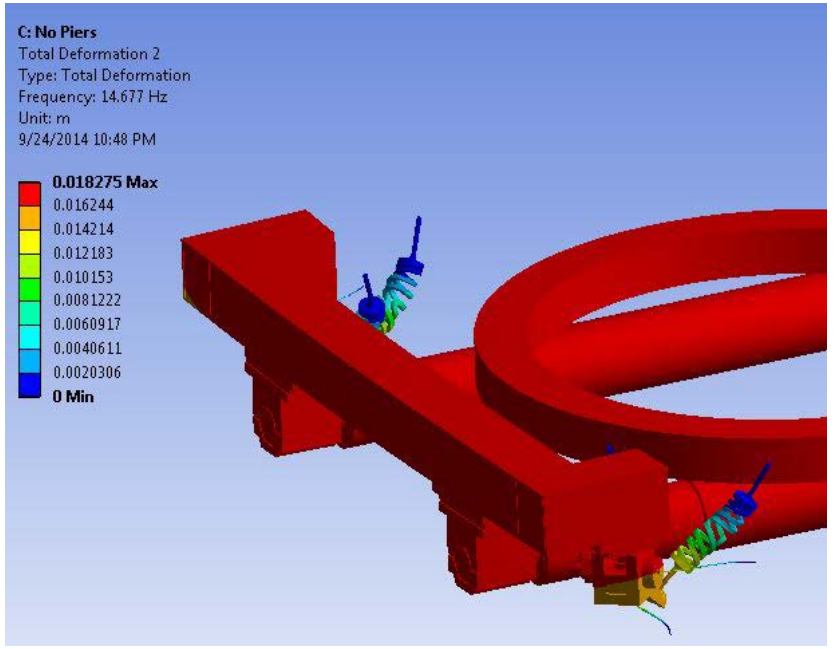


Actuator Addition

- Added actuators based on Brian's old model at 8 Hz
- Frequency more reasonable, still nothing on the foot motion



Desired K	1.6e7 N/m
E	1.88e11 Pa
Length	0.25 m
Radius	0.0026 m
New Freq	14.68 Hz

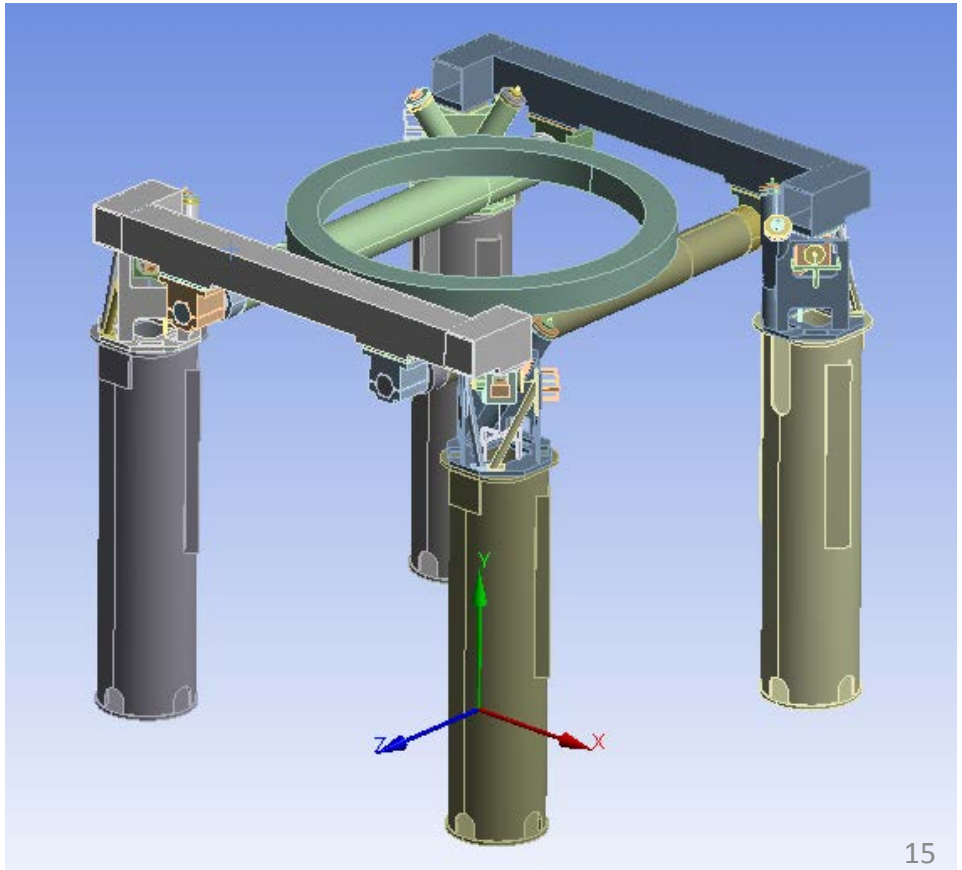


See https://alog.ligo-la.caltech.edu/SEI/index.php?callRep=543

Piers and Full Model Setup

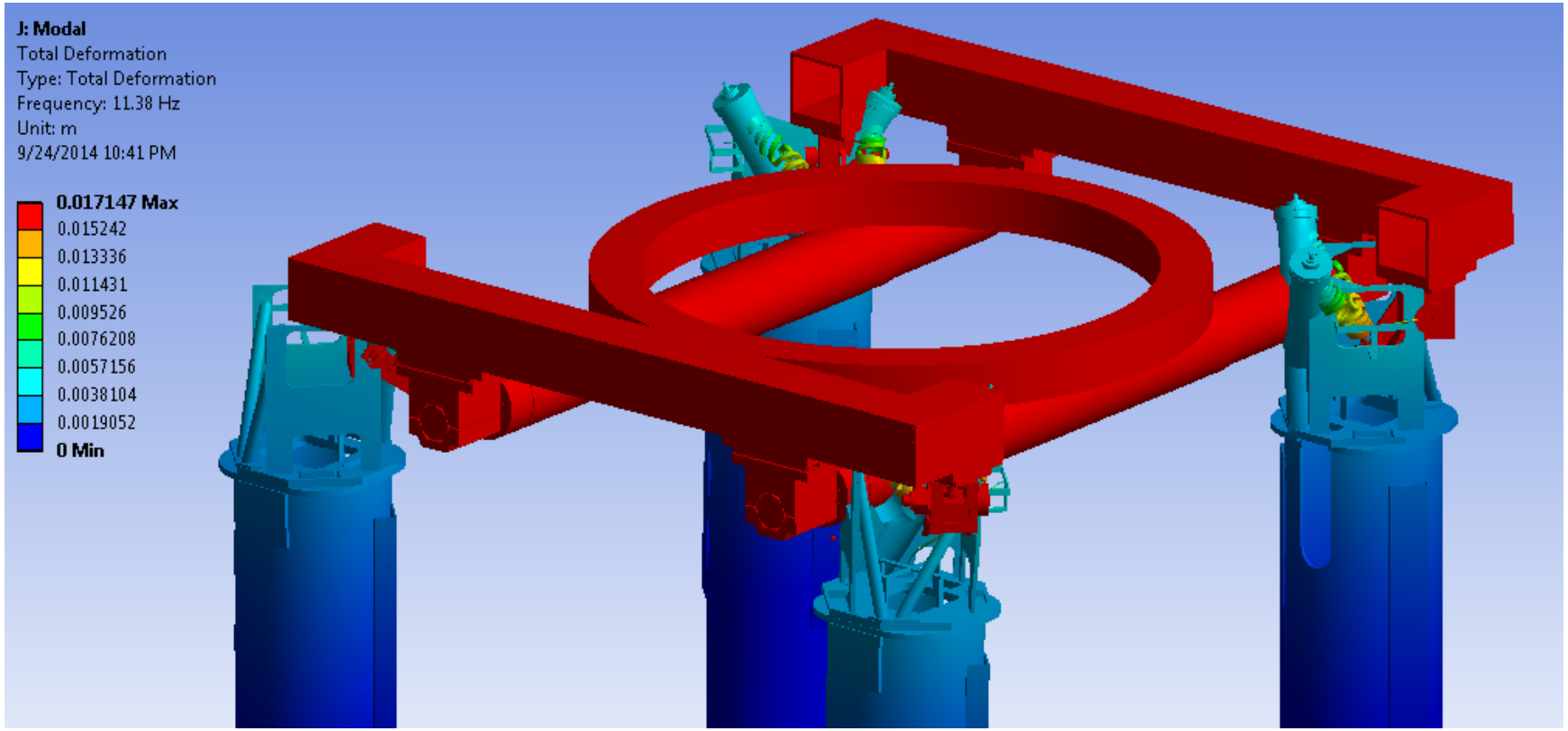
- Added piers, attached end of actuators to pier with stiff structures
- Fixed supports at floor

Component	Mass	Material
Piers	750 kg each	Steel
HEPI Housing	160 each	Steel
HEPI Foot	20 kg each	Steel
Crossbeam	480 kg each	Steel
Support Tube Attach	140 kg each	Steel
Support Tubes	460 kg each	Steel
Stage 0	700 kg	Aluminum
Total Mass w/o Piers/Housing	3220 kg	-
Total Mass	7060 kg	-



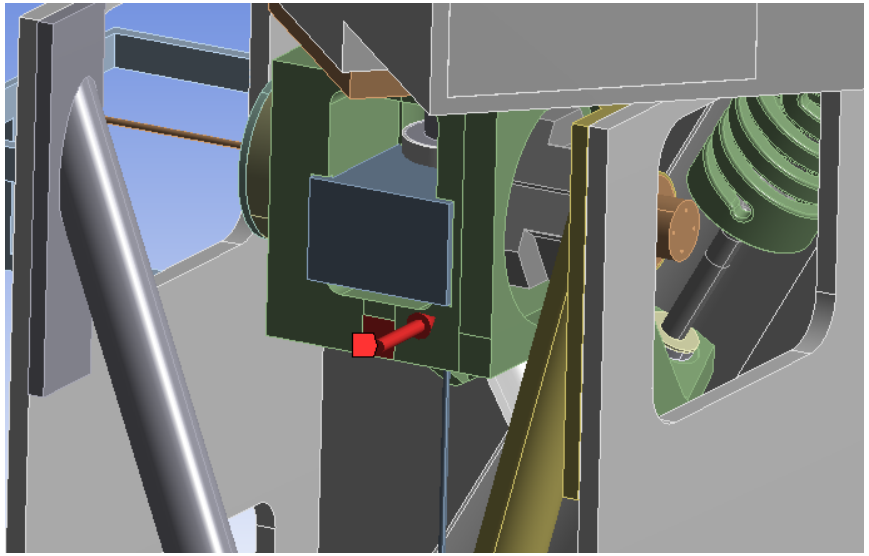
Full Model Results

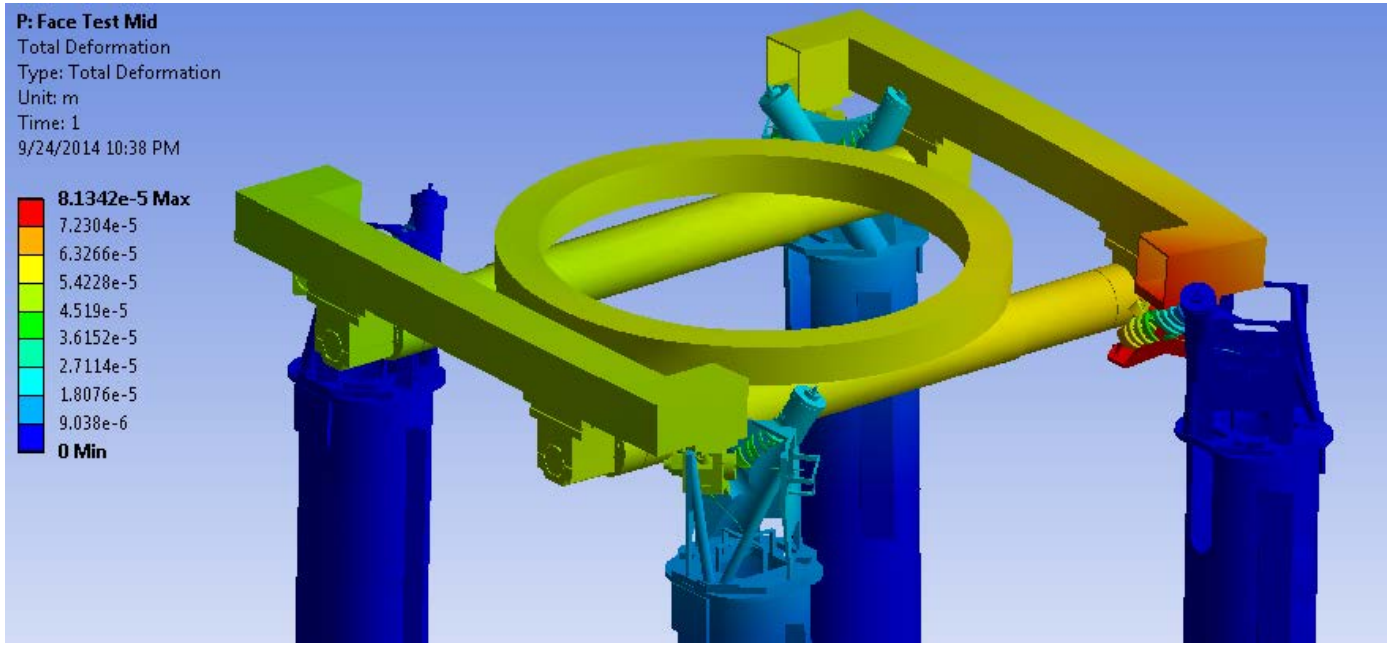
- Beam tube direction mode at 11.4 Hz



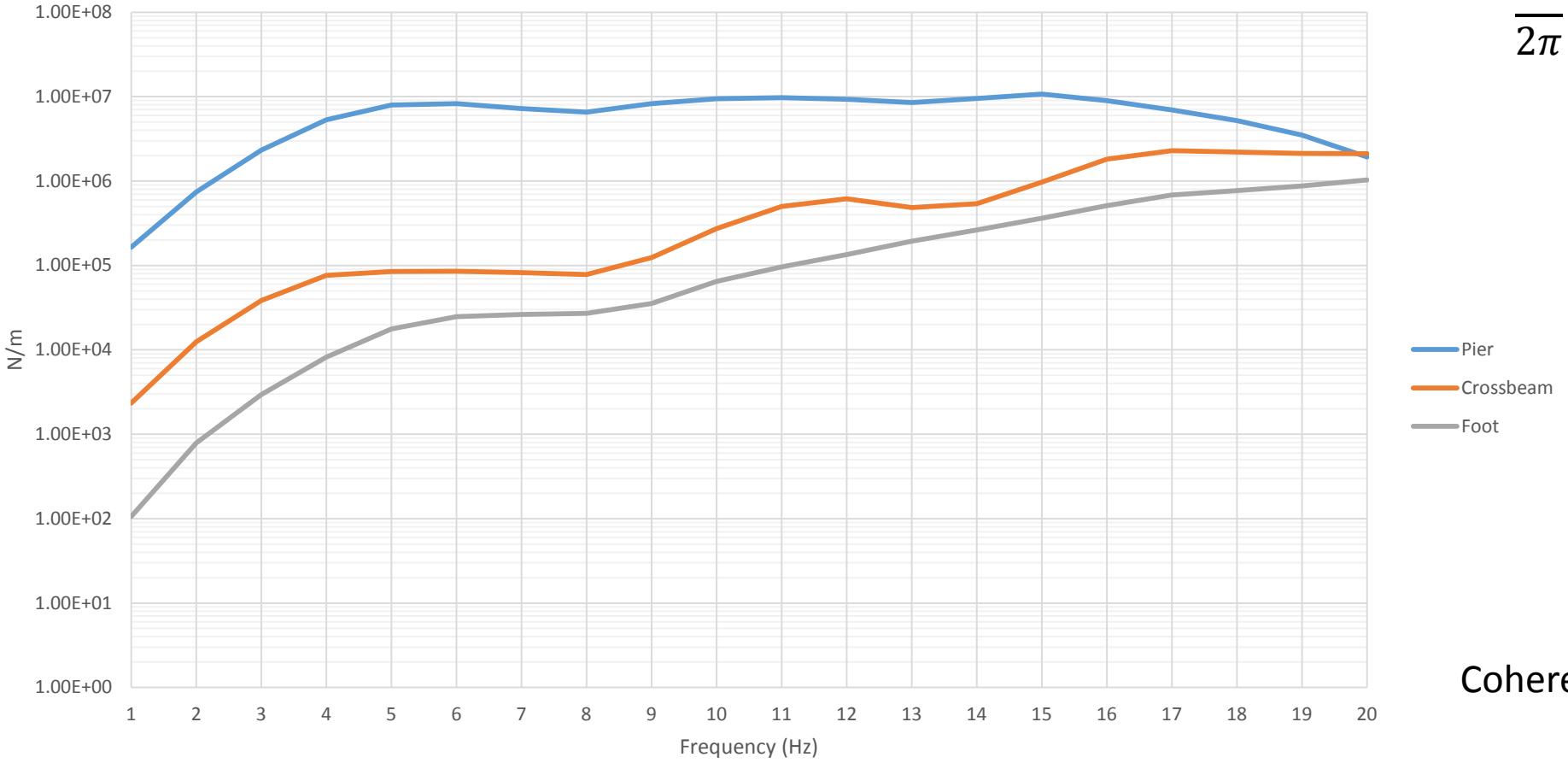
Other Attempts

- Static structural testing at crossbeam and foot
- Response spectra at crossbeam and foot
- No new insight





Stiffness Data from Measurements



$$\frac{1}{2\pi}\sqrt{\frac{1e7\ N/m}{3220\ kg}} = 8.9\ Hz$$

Coherence above 0.9

Proposed Solutions

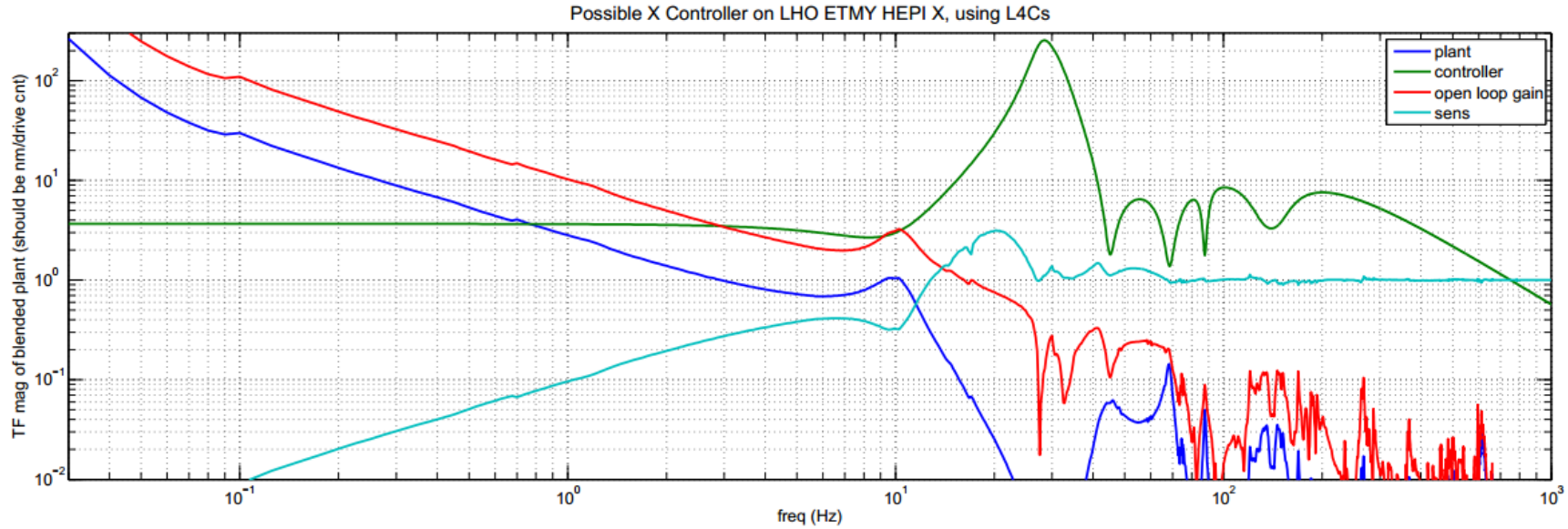
- Add another actuator
  - Likely not possible due to space and construction issues
- See if the mode can be controlled with existing actuators
- Replace/modify the crossbeam
- Add vibration absorbers to crossbeam
- Stiffen the piers
- Reaction mass actuator

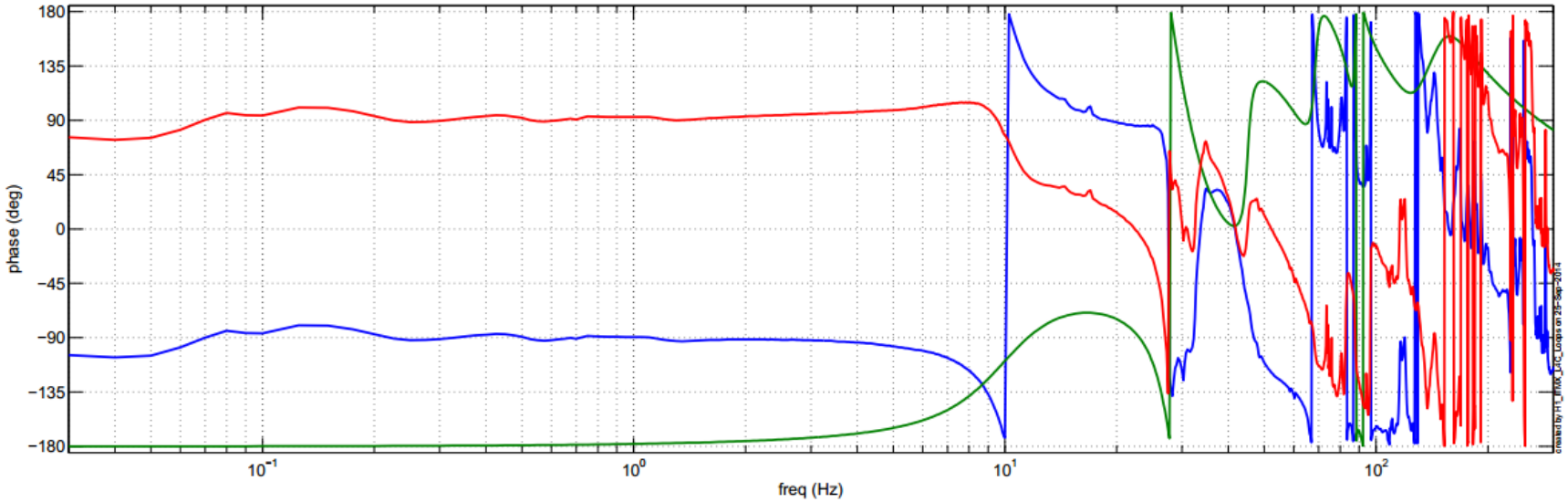
Next Steps

- Get foot measurement resolved
  - Will determine usefulness of crossbeam modification
- Paper study of controller for 8 Hz mode
  - Can it be controlled with existing system?
- Create models of passive and active damping systems
  - Determine feasibility
- Create model with additional actuator
  - Probably not practical
- Create model with stiffer piers
  - Could make HEPI control simpler

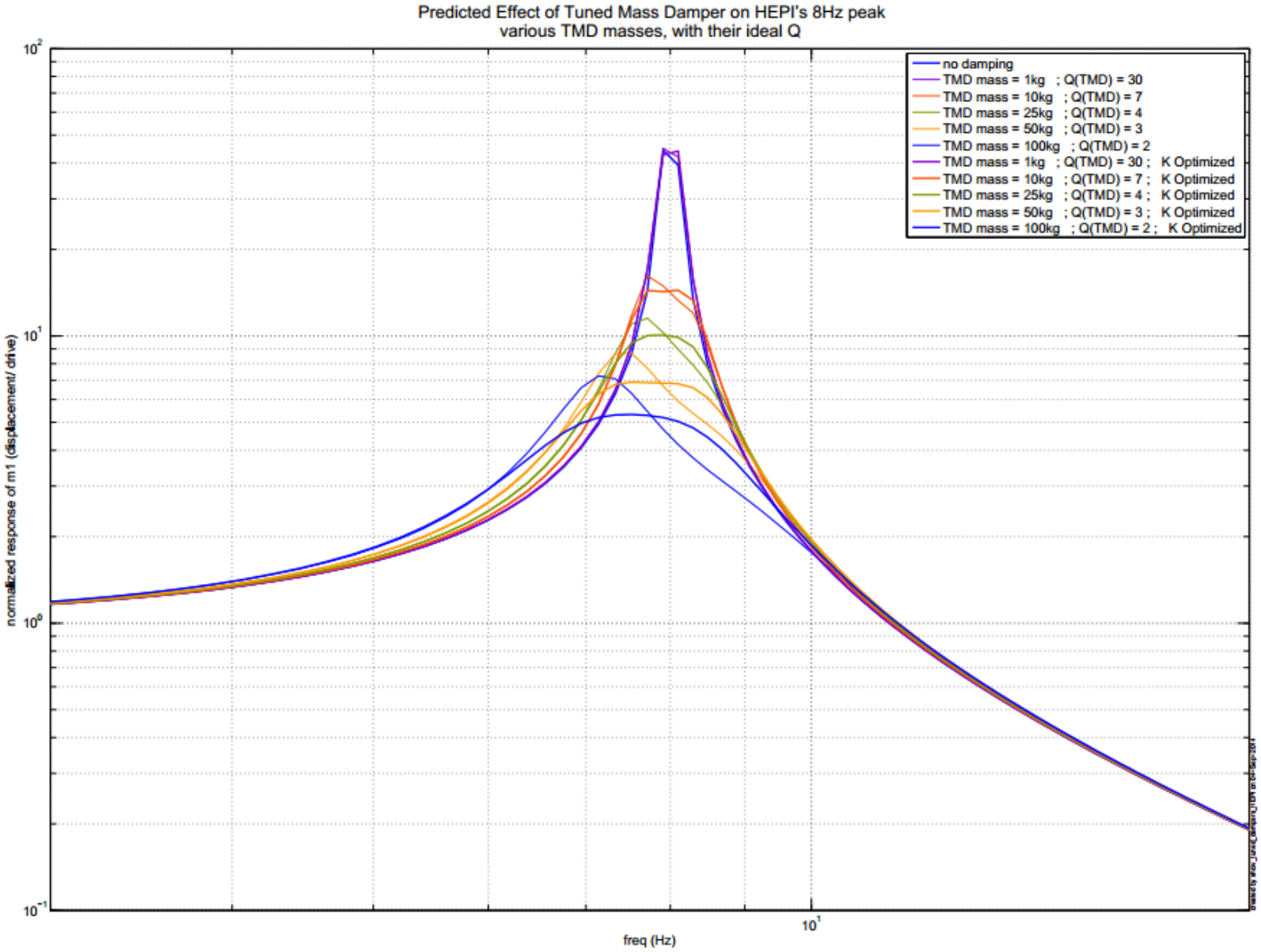
$$\frac{1}{2\pi}\sqrt{\frac{1e7\ N/m}{3220\ kg}} = 8.9\ Hz \quad \Rightarrow \quad \frac{1}{2\pi}\sqrt{\frac{4e7\ N/m}{3220\ kg}} = 17.7\ Hz$$

Extra Slides





/SeismicSVN/seismic/HEPI/Stanford/Transfer/2014_09_25_H1_ETMY_HEPI_Controller/



SeiSVN/seismic/Common/Documents/2014_09_04_HEPI_TMDs/