Determining the Effect of Acoustic Coupling on Advanced LIGO

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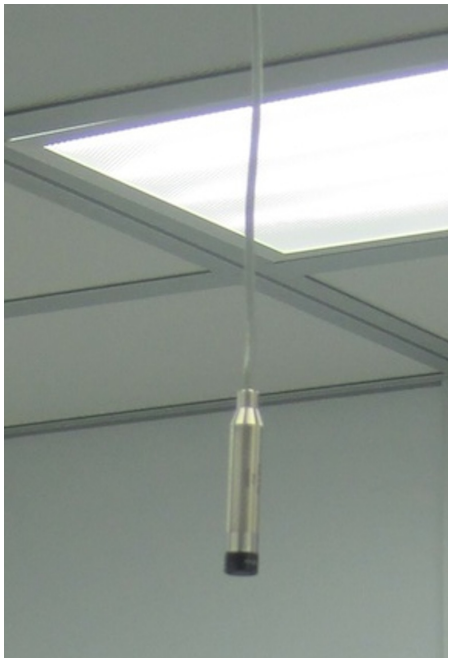
Overview

1. PEM at LIGO
2. Creating a Program to Calculate Environmental Effects
3. Acoustic Coupling
4. Acoustic Coupling Studies
5. Flexure Damping Studies
6. Conclusions
7. Acknowledgements

PEM at LIGO

- Advanced LIGO is designed to be sensitive to movements of the test mass as low as $10^{-20}\ m/\sqrt{Hz}$
- Many other signals other than gravitational waves can be detected
- PEM team responsible for environmental sensors including:
  - Microphones
  - Magnetometers
  - Accelerometers
  - Seismometers
  - Radio Receivers



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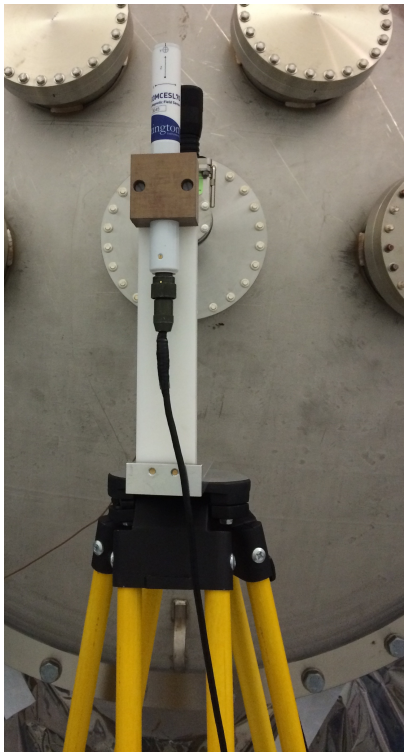
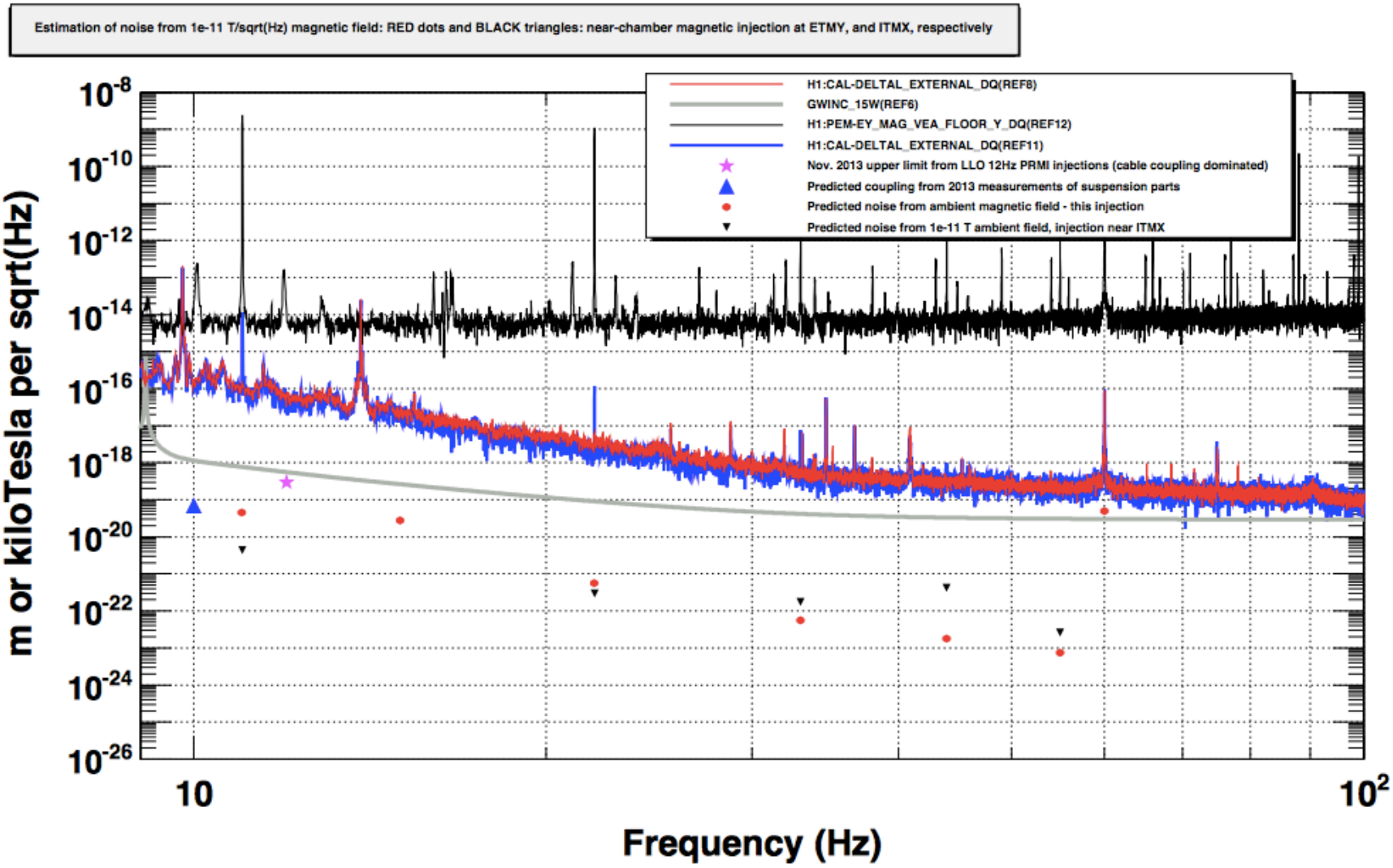


PEM Injections



*T0=17/04/2015 23:45:35 *Avg=1 *BW=0.0117178

A Program to Calculate Environmental Effects

- Program developed in Python
- Utilizes exported DTT text files
- Requires an ambient spectrum and an injection spectrum
- Assumes linearity
- Only calculates effect if signal is 10 times larger than background and DARM is 1.5 times larger than background
- Calculates the upper limit of coupling when injections do not produce peaks in DARM
- Outputs text files with coupling factors and noise estimates
- Final program allows for signals from up to 7 different sensors
- Option to produce a file with only data in rank (highest, lowest, etc.) or median of all data at each frequency

Acoustic Coupling: What is it?

- When sound travels it creates pressure change in the air
- Ways acoustic pressure fluctuations can affect DARM:
  - Shakes vacuum chamber walls: modulates the tiny fraction of scattered light that hits the walls and returns to the beam
  - Shakes external parts of the seismic isolation system: vibrations travel through the isolation system and shake the mirrors in vacuum that the laser beam hits, shaking the beam and producing noise in DARM
  - Shakes mirrors and optics directly in air: the shaking produces noise in DARM

Acoustic Coupling Injections

1. Speakers used to test entire system
2. Shakers placed on single HAMs or BSCs
3. Reaching into HAM and plucking flexure

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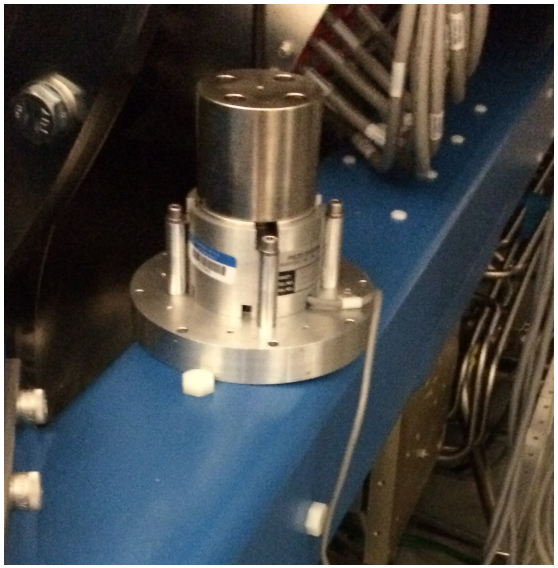
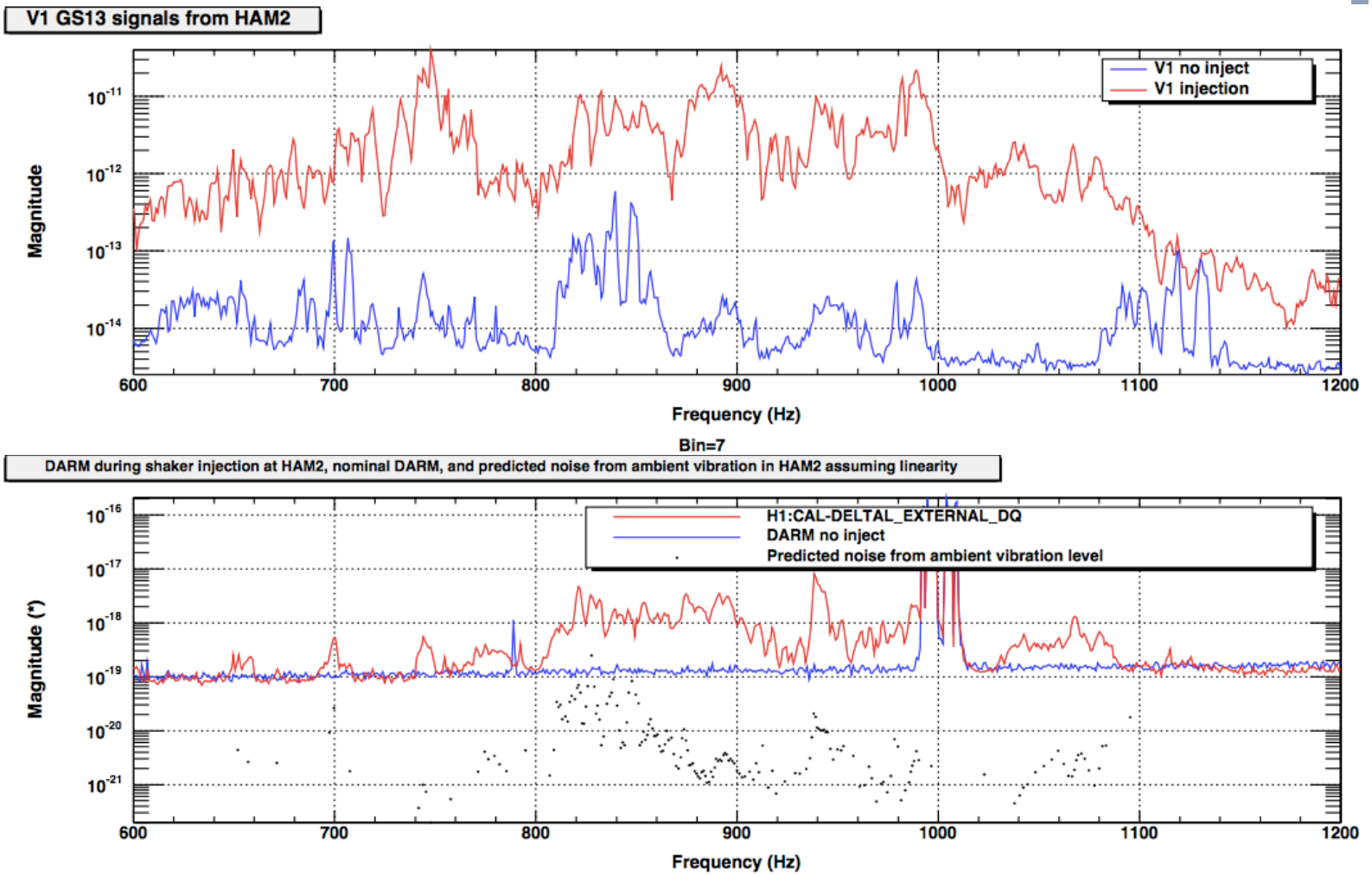


Acoustic Coupling Testing Progress

- Shaker tests on all HAMs and BSCs
- Analyzing data to calculate estimated effect from environmental signal and upper limits of non-peaks
- Creating a ranking of chambers most affected by acoustic coupling

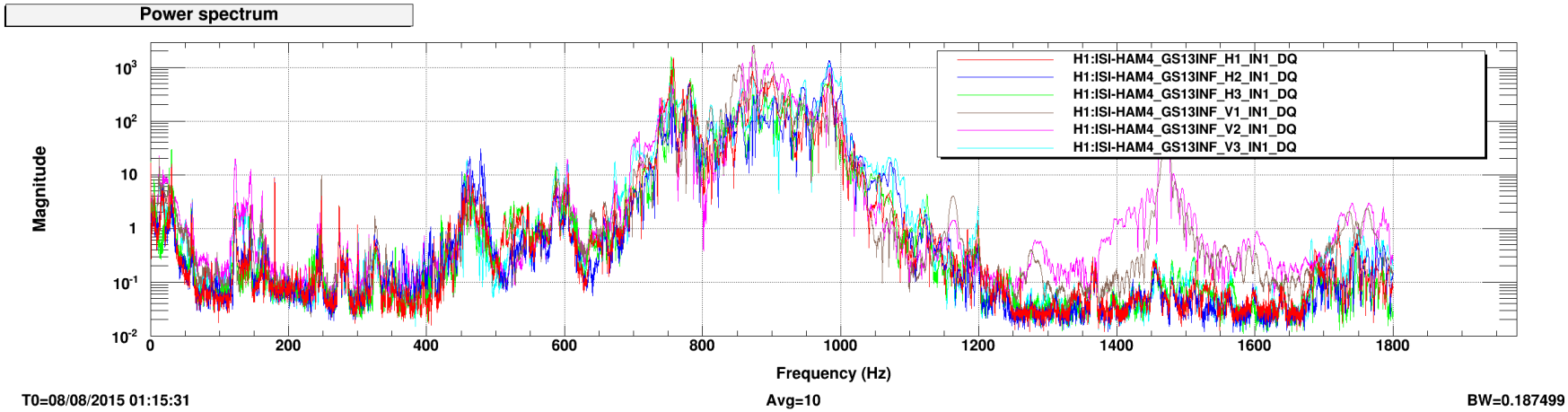
HAM 2

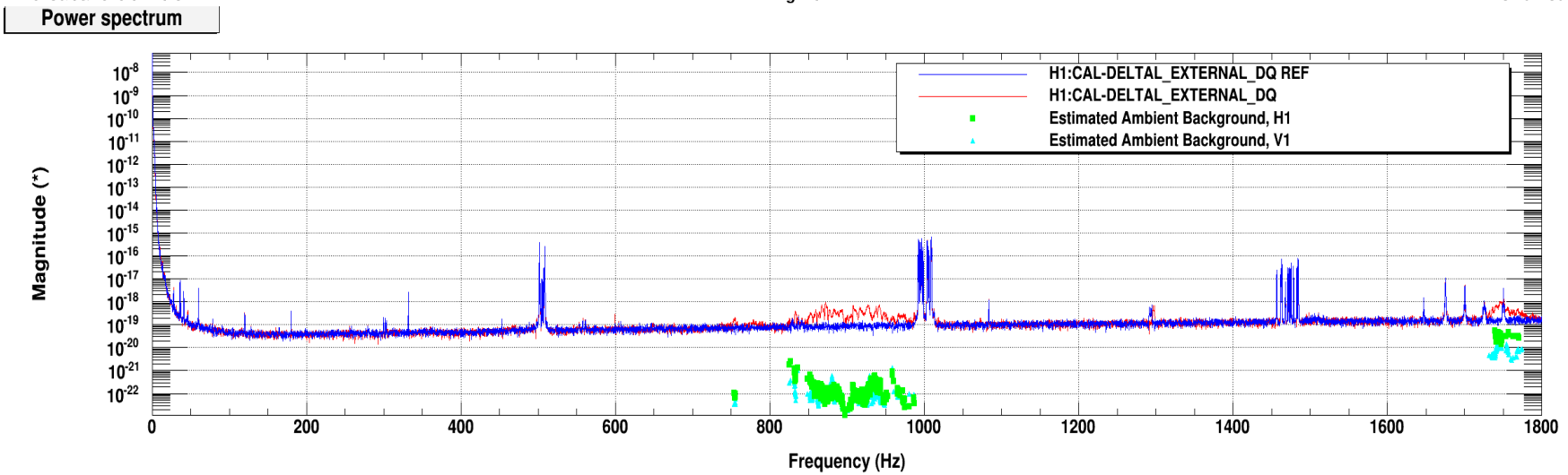
- Large area of raised DARM signal
- Average high estimate between 10^-19 and 10^-20 $m/\sqrt{Hz}$



HAM 4

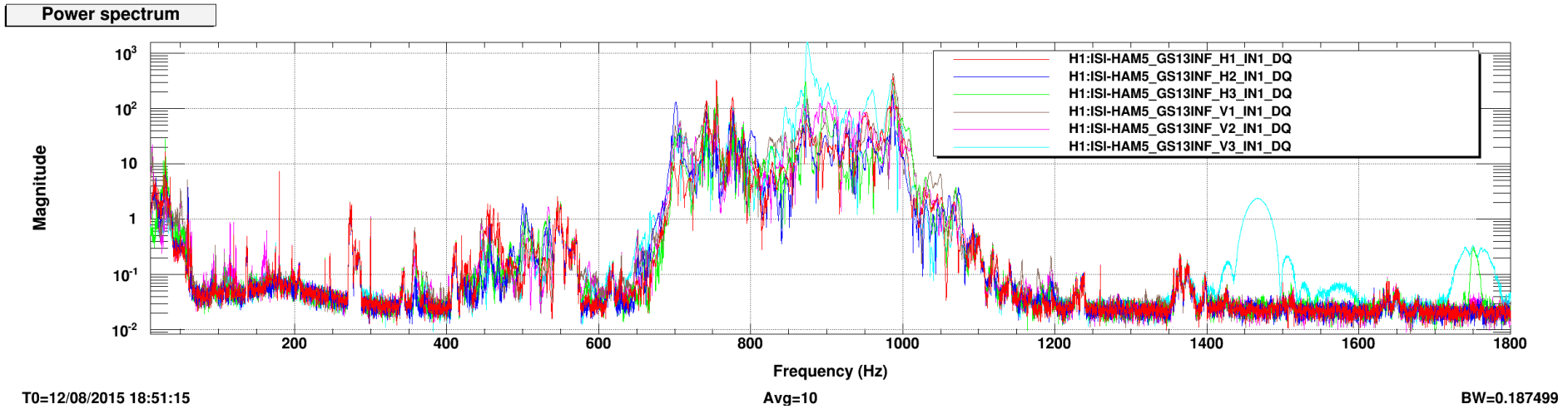
- Created increase in DARM between 800 and 1000 Hz
- Signs of upconversion
- Average estimates around 10^-21 $m/\sqrt{Hz}$

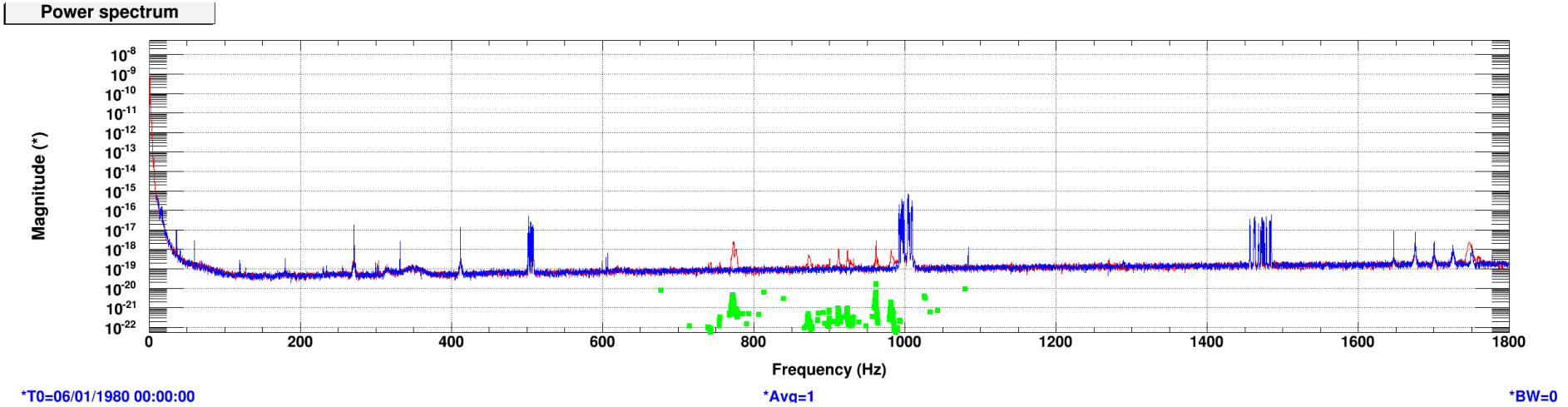




HAM 5

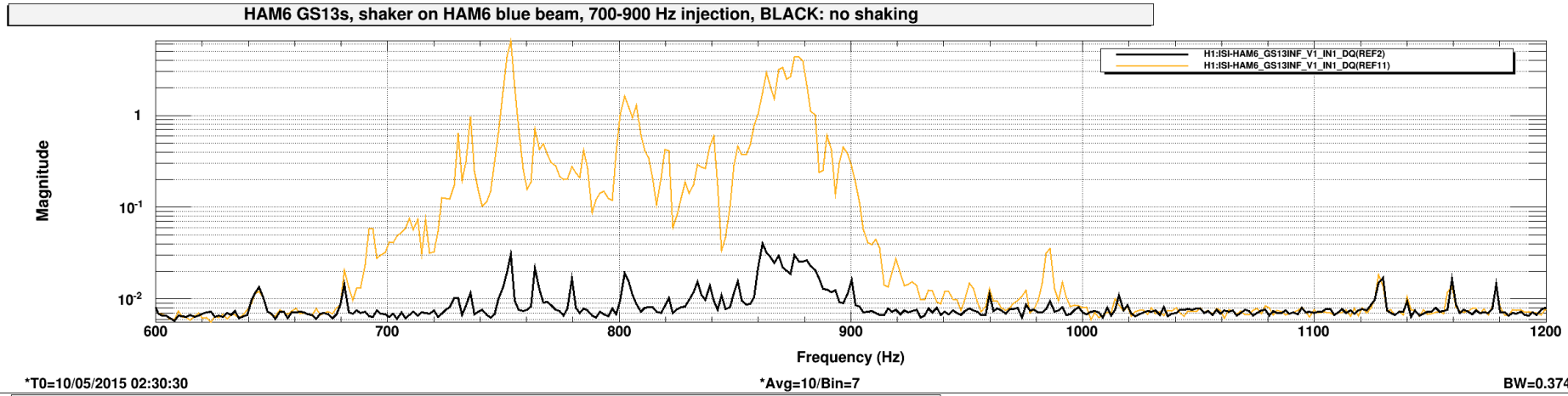
- Few small peaks created in DARM
- Average high estimate between 10^-20 and 10^-21 $m/\sqrt{Hz}$

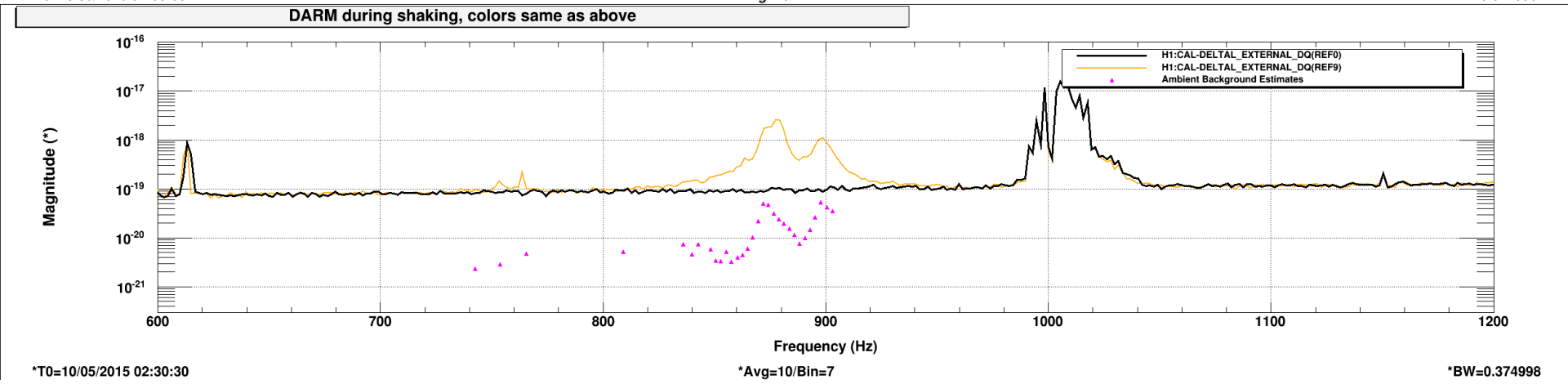




HAM 6

- Few peaks produced in DARM
- Average estimates between 10^-19 and 10^-20 $m/\sqrt{Hz}$





Other HAMS

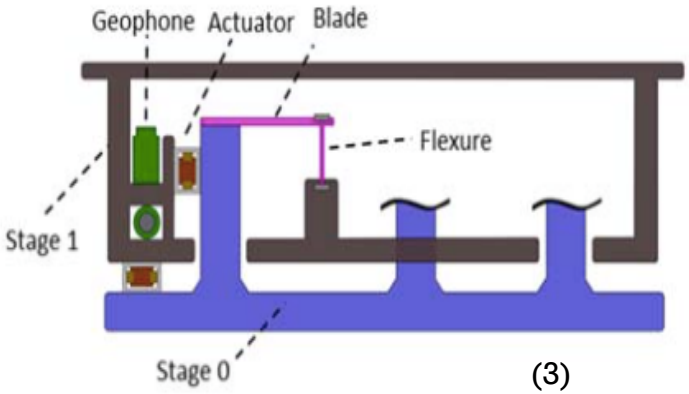
- HAM 1:
  - No geophones within chamber
  - No noticeable change in DARM occurred during injection
- HAM 3:
  - No noticeable change in DARM occurred during injection
  - When calculated by the program, no estimated values were produced

HAM Ranking

1. HAM 2
2. HAM 6
3. HAM 5
4. HAM 4
5. HAMs 1 and 3

HAM 6 Flexure Testing

- 3 Flexures inside HAM connect the two stages
- When HAM 6 was shaken, peaks appeared
- Possibly the result of flexures vibrating at natural frequencies
- Testing with Viton lined clamps to damp



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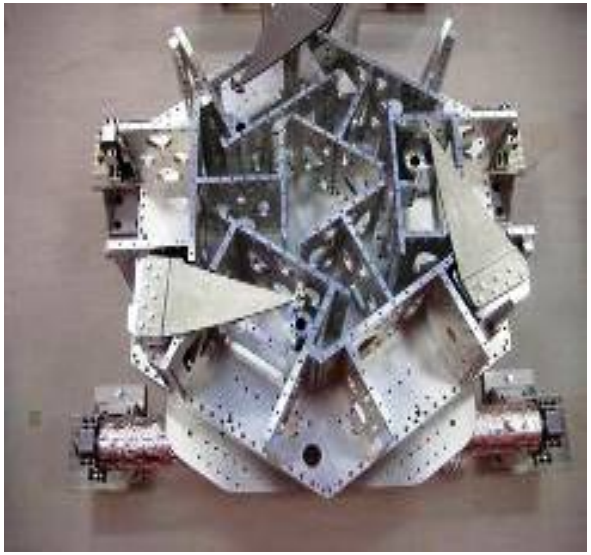

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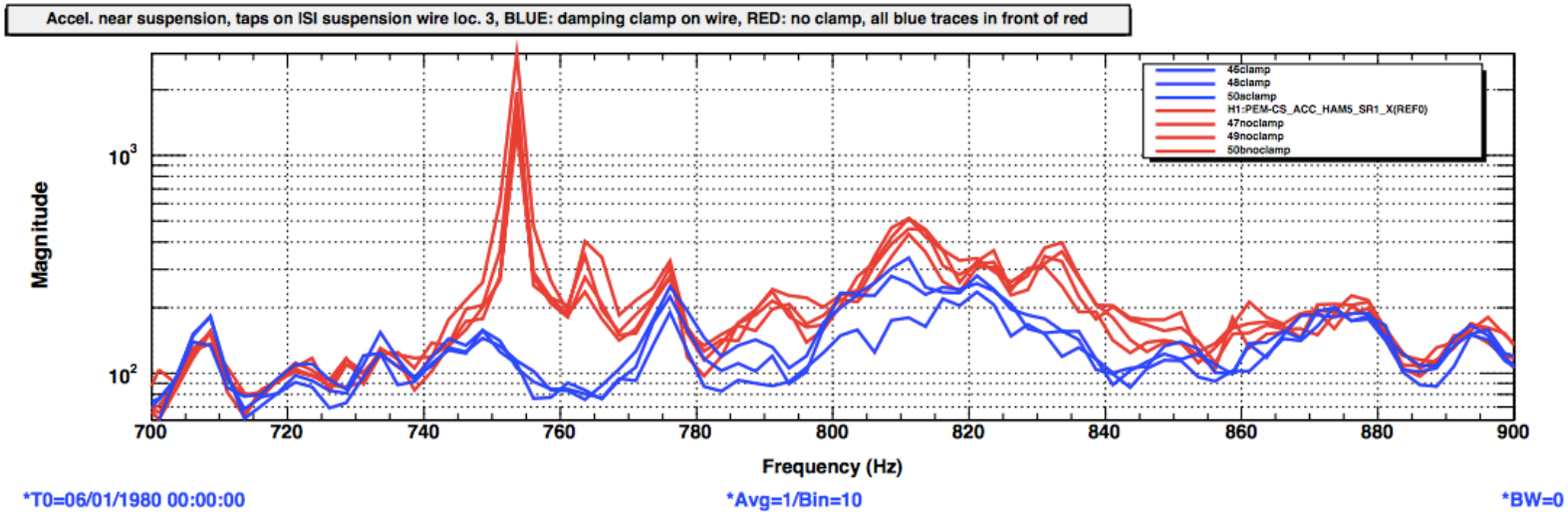
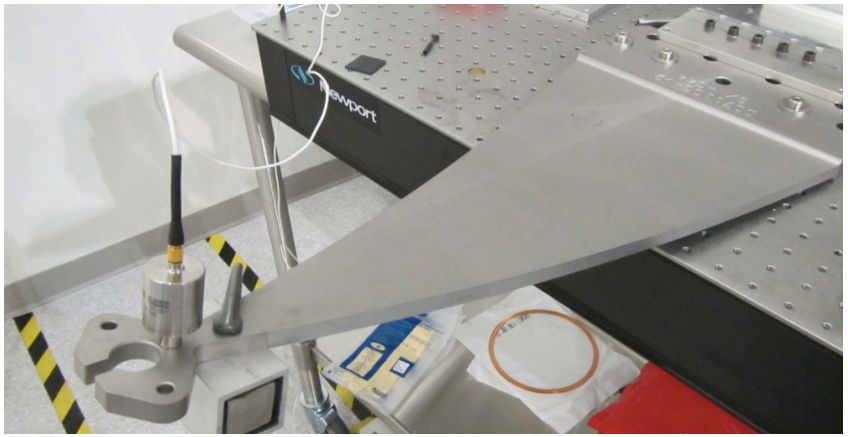
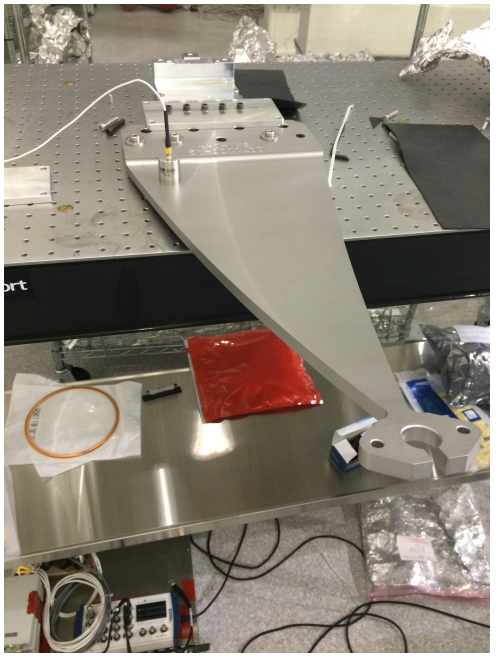
HAM 6 Flexure Testing



- Testing in progress on best way to damp the flexure and blade spring

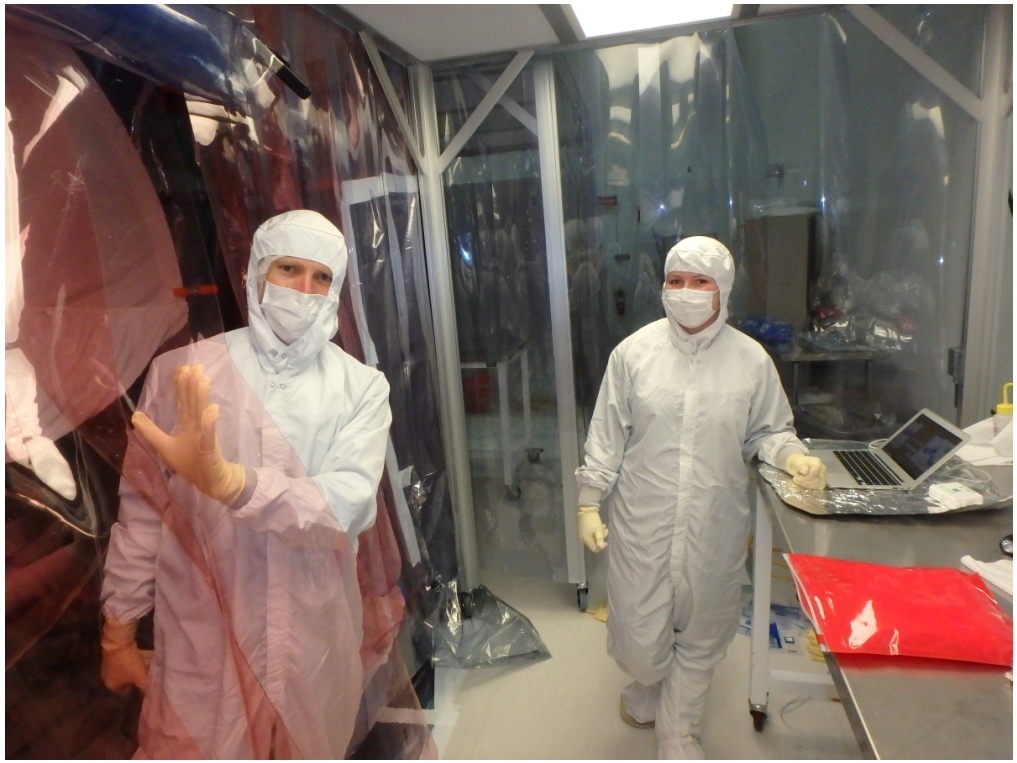




Conclusions

- Program handled data analysis well
- Shaking tests on HAMs revealed sites of acoustic coupling
- BSC data still needs to be analyzed
- Future work:
  - Testing in end stations
  - How to limit acoustic coupling?

Thank you for an exciting and rewarding experience at LIGO!



Acknowledgements:

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References

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