Pre-O3 PEM injections

Philippe Nguyen, Sharan Banagiri, Corey Austin, Kara Merfeld
Anamaria Effler, Robert Schofield

Reports until 19:23, Tuesday 28 May 2019

H1 PEM EDIT ADD COMMENT Link

robert.schofield@LIGO.ORG - posted 19:23, Tuesday 28 May 2019 (49521)

Pre-O3 PEM injection summary and links to individual logs

Philippe Nguyen, Corey Austin, Sharan Banagiri, Kara Merfeld, Anamaria Effler, Robert Schofield

O3 initial PEM injections took place mainly the weeks of March 25 at LLO and March 18 and April 15 at LHO. Hundreds of injections were made at tens of locations including acoustic, magnetic, shaking, impulse and RF injections (DTT files: https://lhocds.ligo-wa.caltech.edu/exports/pem/19aMarPEMinjections/LHO). A preliminary report was prepared, https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=47881, we reference it below when it contains more detail then presented here.

A. Vibration coupling

1) Worst site: LLO EX transmission monitor

The large drops visible in LLO's range as anthropogenic vibration levels increase, are associated with the EX transmission monitor. The noise has a higher SNR in the pitch and yaw signals from the quad diodes than it does in DARM. Thus, the diodes witness the noise before it is combined with other noise in DARM. Candidates include scattering and servo noise. https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=46147

2) Next worst sites: at LLO are EY and HAM5/6 and, at LHO, HAM5/6 and the PSL followed by EY

Figure 1 indicates the sites at LHO and LLO where the ambient vibration level is estimated to make the greatest roughly linear contribution to DARM for each frequency. A rough summary of the LHO plot is that, the greatest ambient vibration contribution to DARM is in the HAM5/6 area below 100 Hz, and in the PSL area above 100 Hz. The rough summary for LLO is that the worst sites are HAM5/6 and EY, and both are a significant contribution to DARM below 100 Hz.

The plots are made by first calculating a coupling function (meters of DARM per meter of motion at sensor) for each sensor for each of multiple injections, and then producing a single coupling function for each sensor, using an algorithm to select the best of the multiple injections, usually the loudest relative to other sensors. The coupling function is multiplied by the ambient vibration level to produce an estimate of the ambient contribution to DARM. At each frequency in the plot, the sensor or sensor region with the highest estimated contribution to DARM is indicated by color, and the estimated contribution plotted.

Introduction

A. Vibration coupling, worst sites

1) LLO EX transmission monitor

2) Next worst sites at LLO are EY and HAM5/6 and, at LHO, HAM5/6 and the PSL

3) At both sites, HAM5/6 coupling is likely at the septum

4) EY coupling at LLO is likely in the manifold, at LHO, it may in the ETMY chamber

5) HAM5/6 coupling at the septum window?

Other beam spots on LLO HAM6

OMC REFL beam not the cause of the main HAM5/6 scattering

HAM6 witness search at LLO

6) IO jitter coupling at both sites

7) Comparison of EY and EX in-lock photos

8) Shaker injections at EY produce noise similar to some anthropogenic noise

9) Other vibration coupling

Beamtube shaking

Coupling at LHO BS chamber and at the reduction flanges by the optical lever

48 Hz peak at LHO

Reduction of 58 Hz chiller peak at LHO:

10) Vibration coupling not seen (at least 10 below DARM)

11) Coupling estimates from PEM injections correctly predict environmental coupling

LLO DARM glitch near S190510g is correctly predicted from PEM injection coupling functions.

Range reduction from LHO HVAC is roughly predicted from estimates for HAM5/6.

Range reduction from rain at LHO is roughly consistent with PEM coupling functions

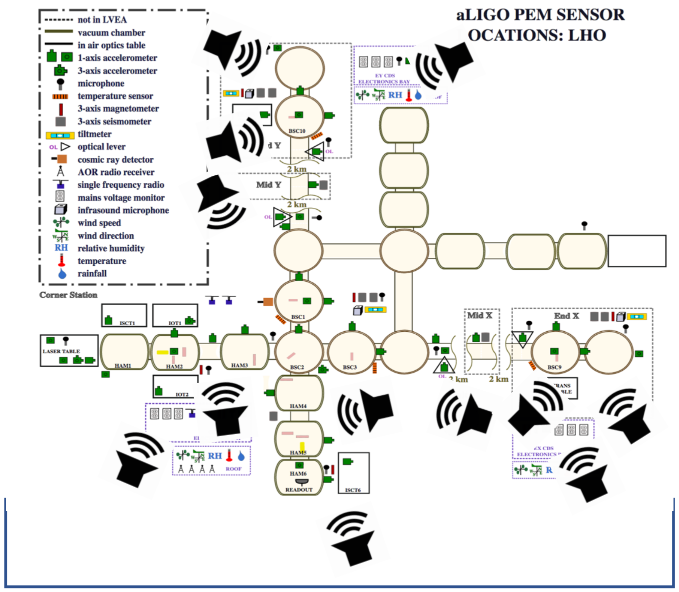
Range reduction from wind at LHO is roughly consistent with PEM coupling functions.

B. Magnetic Coupling

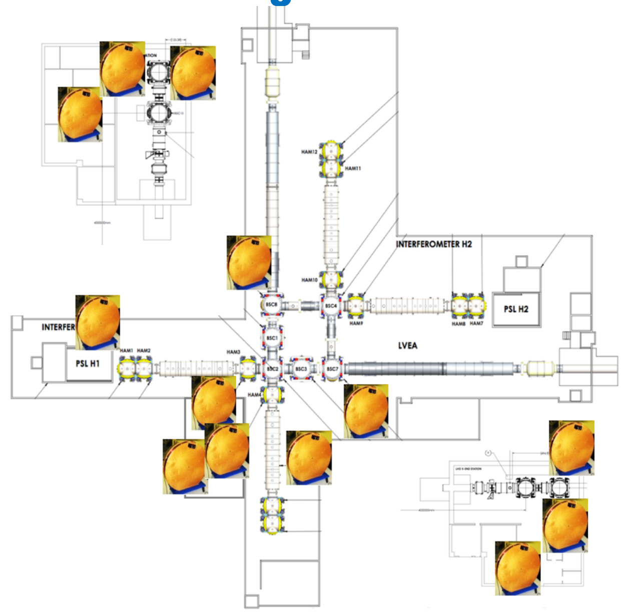
C. RF Coupling

D. Site activities

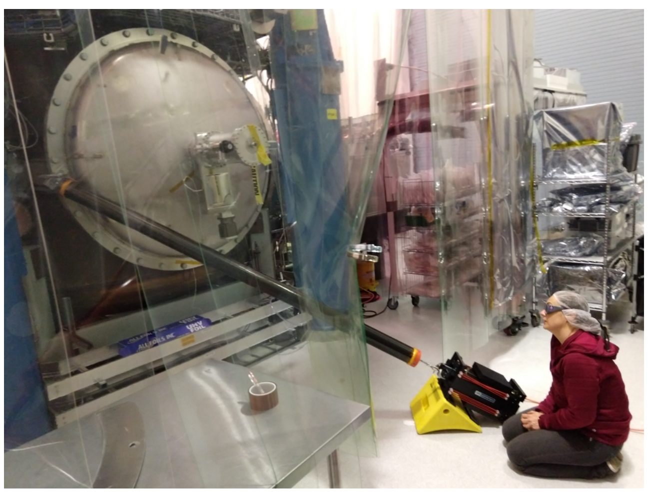
Acoustic



Magnetic



Shaker

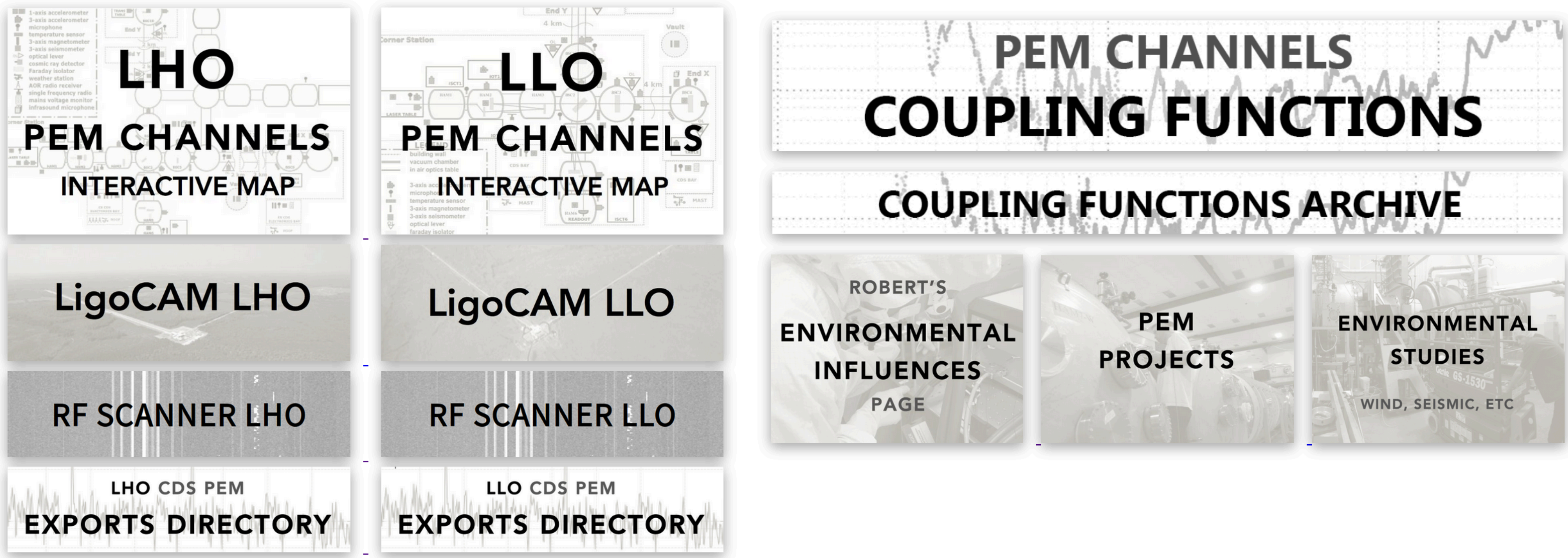


Radio

Impulse

PEM.LIGO.ORG

PEM Central



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B. Magnetic Coupling

C. RF Coupling

D. Site activities

L1 PEM (Detchar, ISC, PEM) Link

robert.schofield@LIGO.ORG - posted 20:12, Wednesday 22 May 2019 - last comment - 13:38, Friday 24 May 2019(46147)

The main source of the anthropogenic drops in LLO range is associated with EX transmission monitor

Corey, Anamaria, Robert

Summary: 1) The big drops in LLO range with anthropogenic vibrations are strongly correlated with what looks like scattered light on the TMX diodes. 2) The range-correlated noise has higher SNR in the TMX diode signals than in DARM, indicating that the TMX diodes witness the noise before it is combined with other noise in DARM.

The PEM team has been working on the question of whether HAM5/6 and EY are the main vibration coupling sites at LLO. EY is certainly an important vibration coupling site that contributes to drops in range. Shaking at EY can produce arches similar to those from some of the daytime noise (https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=46089), and thunder coupling at EY may have contributed to S190510g (https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=46025). The HAM5/6 area is also an important coupling site (e.g. https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=46149), and may be due to scattering from the septum window (https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=48886) But there is a third noise source that more closely correlates with the anthropogenic range drops than the noise produced at EY or HAM5/6: noise that is evident on the EX transmission monitor photodiodes.

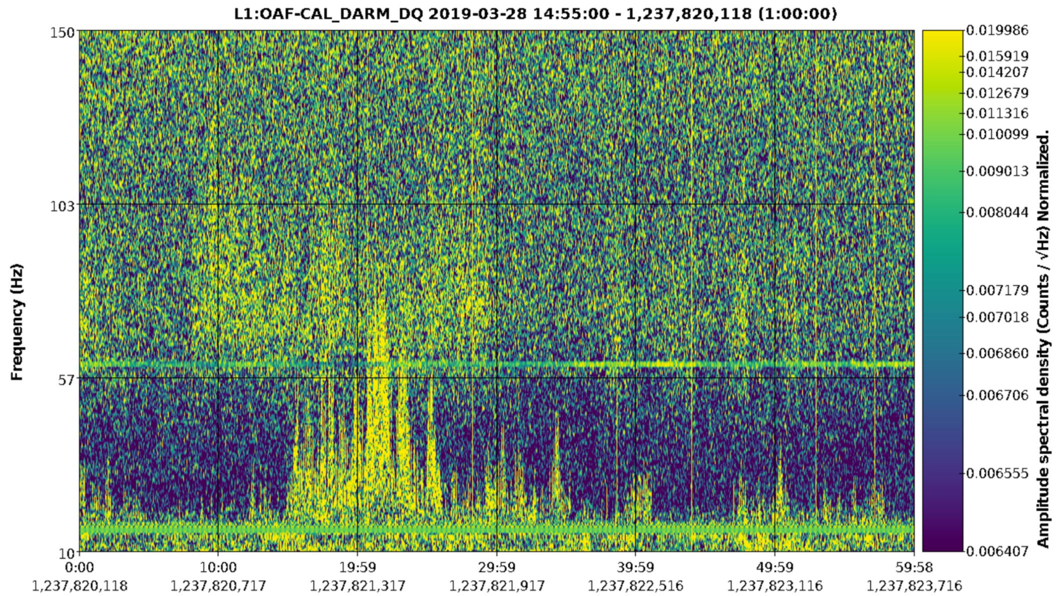
The transmission monitors have been implicated before. In the fall, when DARM was offloaded at upper stages of ETMY, scattering was visible on TMY diodes, now it is offloaded at upper stages of the ETMX suspenson. During PEM injections at LLO we noted a "mystery" scattering in spectrograms that we couldn't explain by shaking the vacuum enclosure. Andy and other DetChar members have noted scattering associated with TMX on multiple occasions.

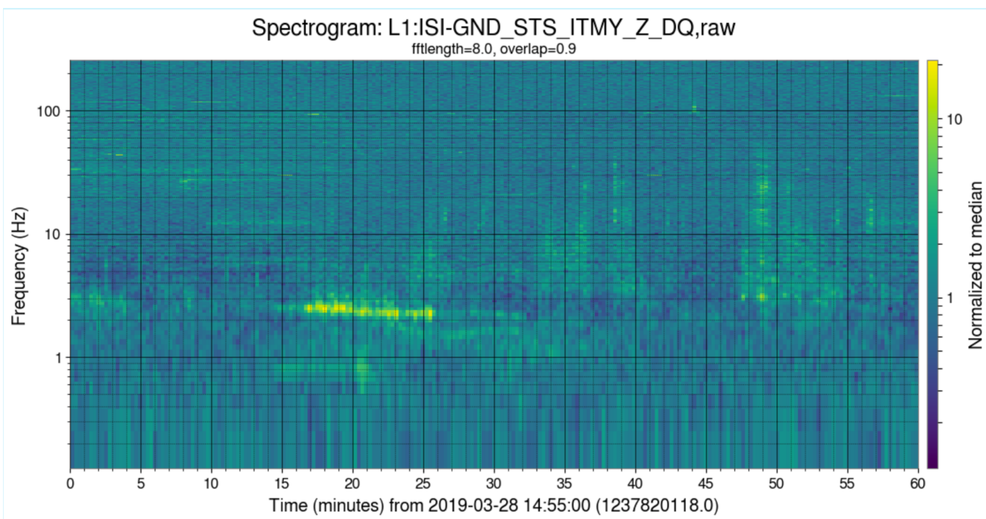
The main points here are, first, that the noise registered on the TMX diodes is the worst anthropogenic-vibration driven noise at LLO, worse than noise produced at HAM5/6 or ETMY, as judged by the detrimental effect on range over multiple days scattered across O3. And, second, that the diodes witness the range-correlated noise with higher SNR than it is seen in DARM and so the diodes are "upstream" from DARM, that is, see the noise before the SNR is reduced by other noise in DARM.

Figure 1 shows that the big workday drops in range are nearly perfectly correlated with noise in TMX photodiodes, noise that has a higher SNR than the noise in DARM. The other scattering noise (such as from EY) is visible in the spectrograms, but it does not correlate nearly as well with the range drops. The TMX noise is almost continuous, and only shows in DARM when the apparent scattering shelf reaches the most sensitive band in DARM.

In order for the SNR to be bigger on the TMX diodes (assuming that the diodes are seeing scattered light), the fraction of scattered light must be much greater at the diode than in DARM. Otherwise we could detect gravitational waves better with the TMX diode than with the OMC diodes. So, it is likely that the entire parasitic cavity is behind the EX test mass. One possibility is that there is a parasitic cavity between the TMX and ETMX (or, less likely, the annular RMX). Another is that the "cavity" is within the TMX itself, modulated by the entry

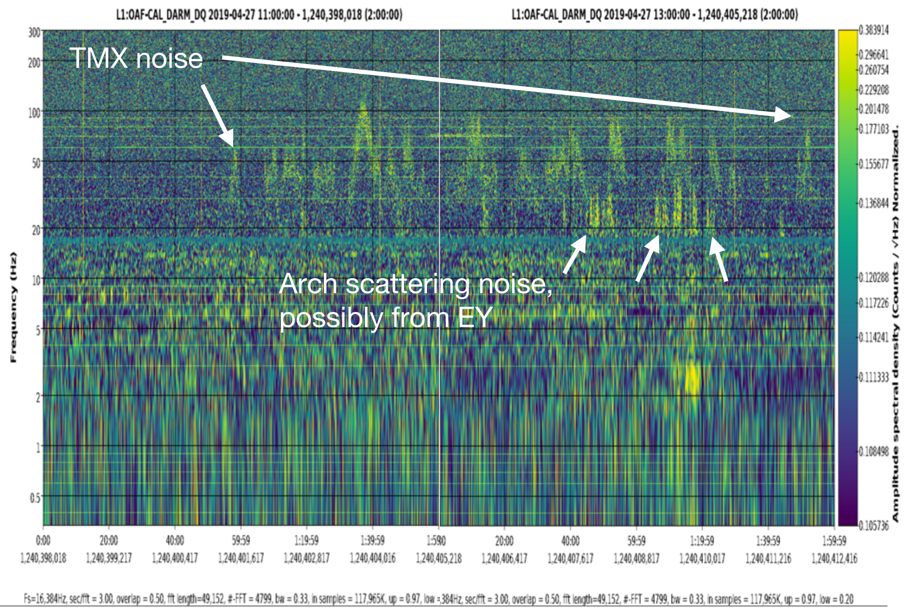
Two types of scatter-like noise

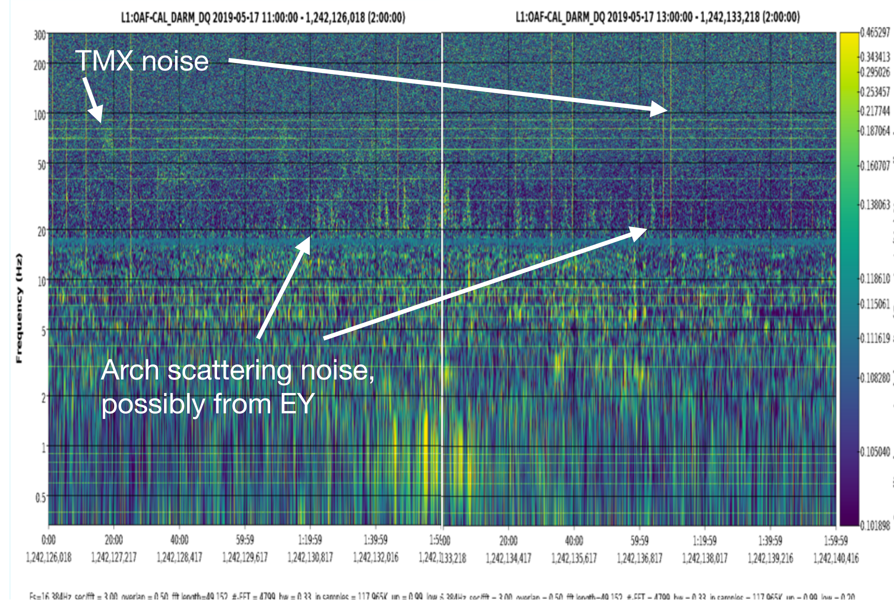




April 27 **May 17**

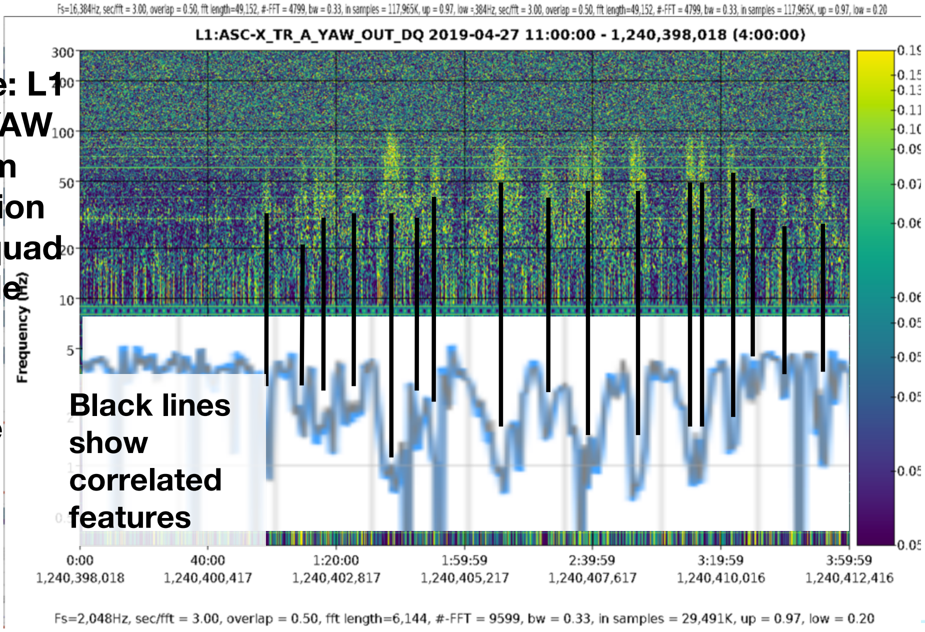
L1 DARM 4 hours

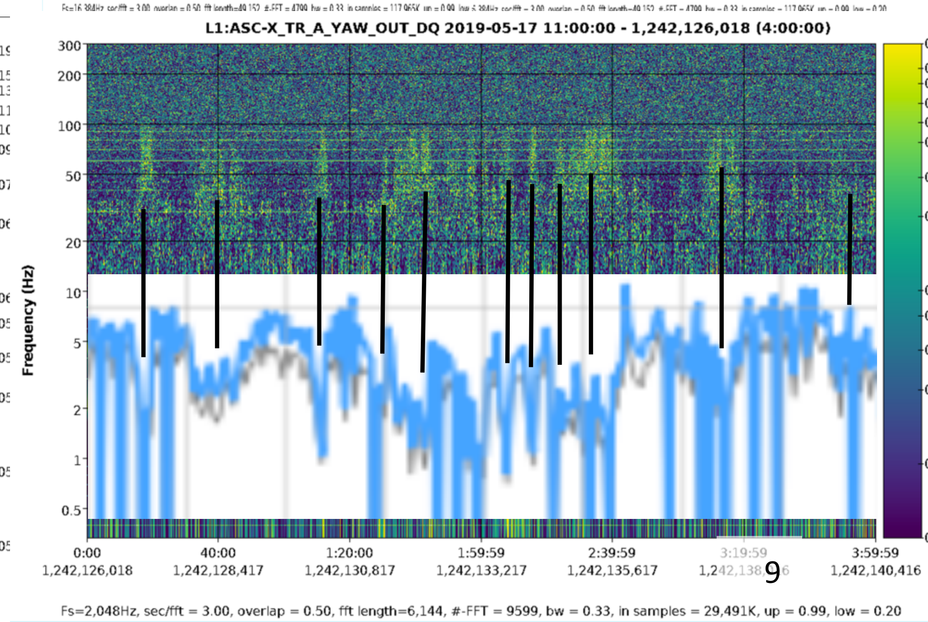




TMX noise: L1 X_TR_A_YAW signal from transmission monitor quad photodiode

L1 range

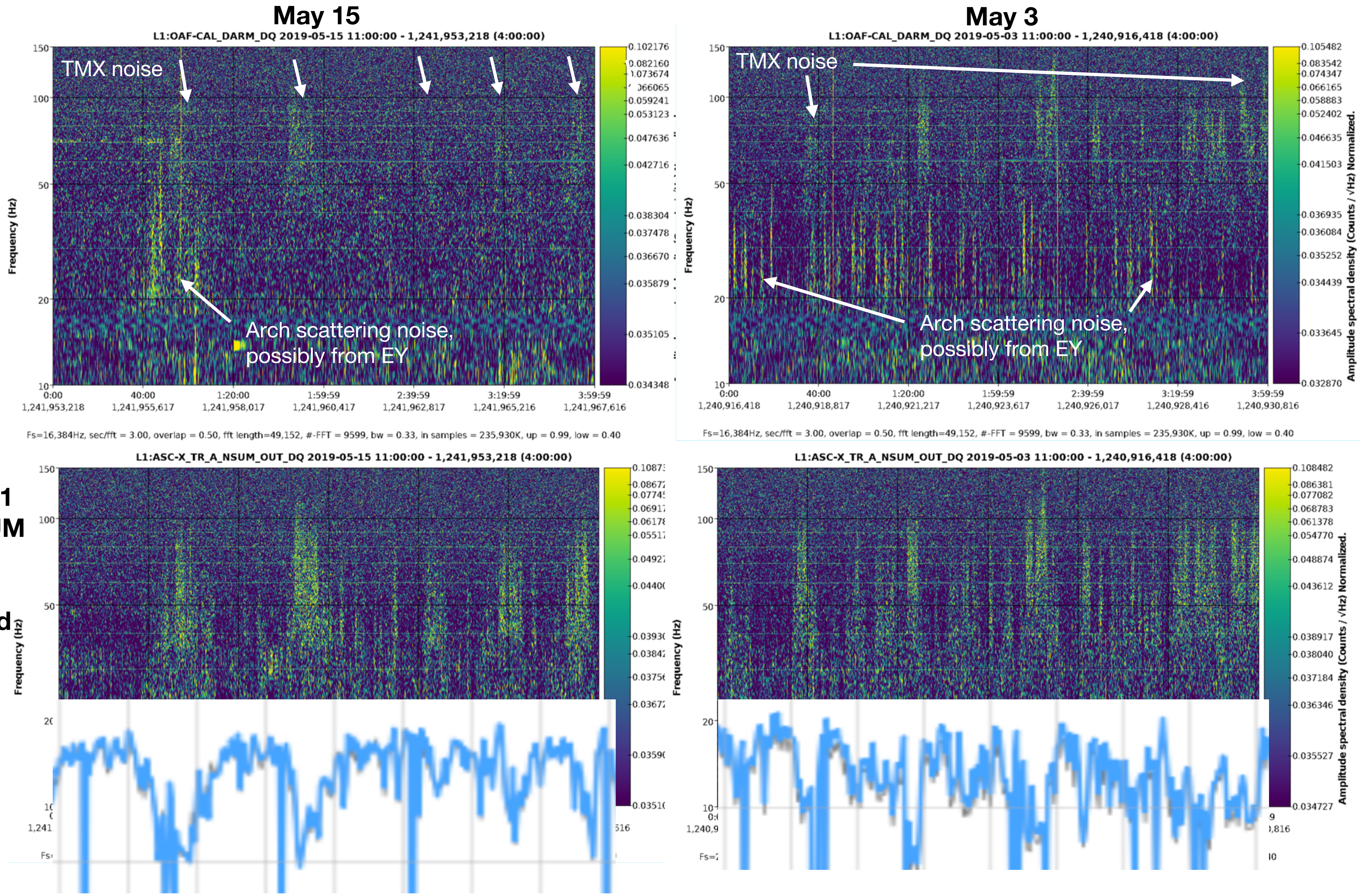


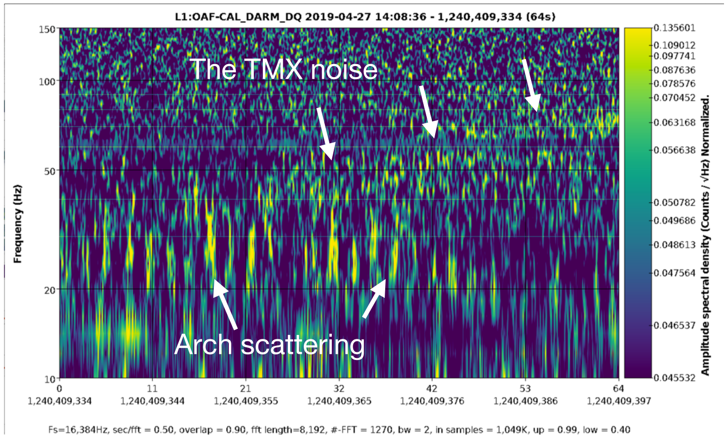


L1 DARM
4 hours

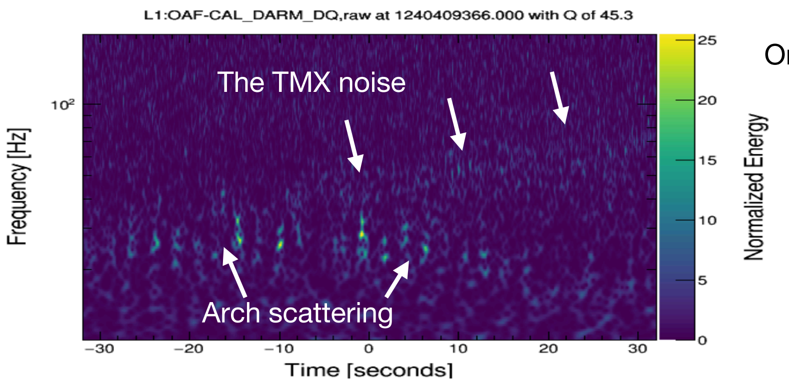
TMX noise: L1 X_TR_A_NSUM signal from transmission monitor quad photodiode

L1 range

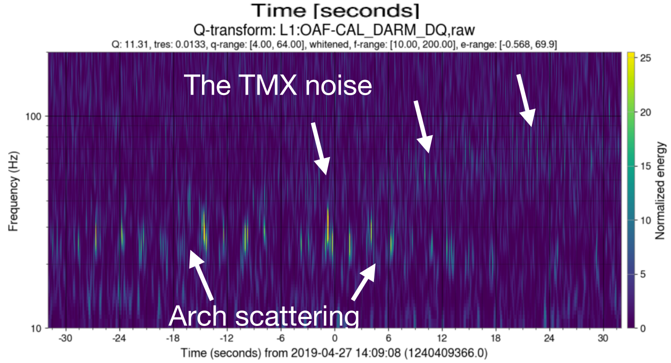




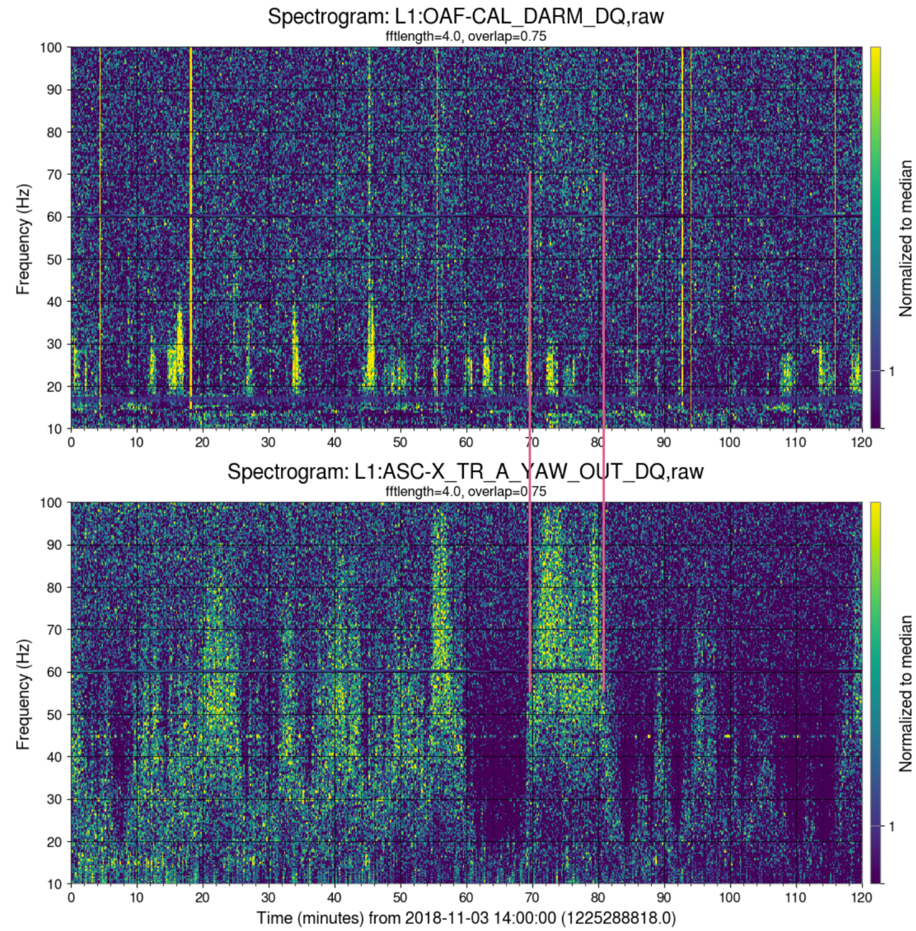
Spectrogram



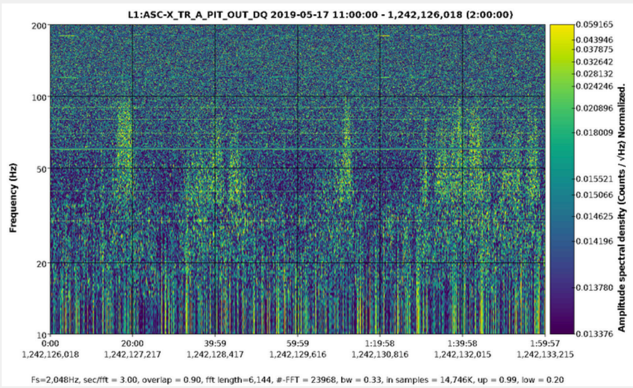
Omega scan

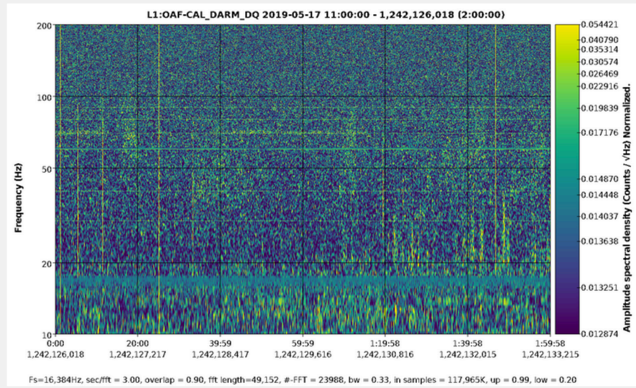


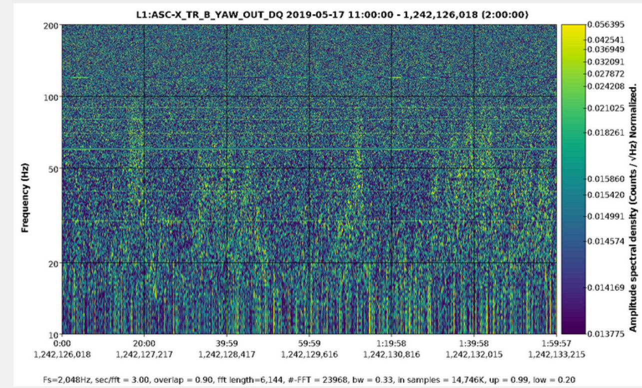
Q-transform
Same settings

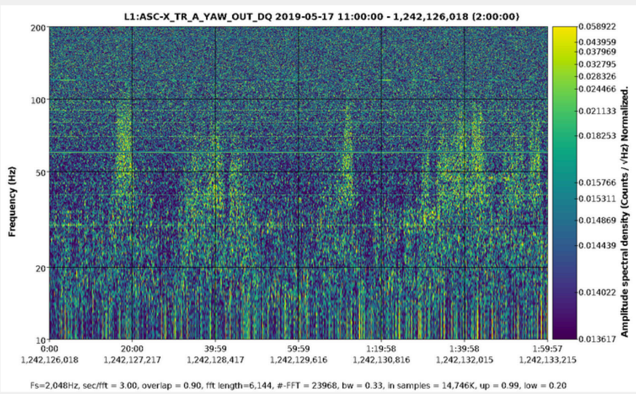


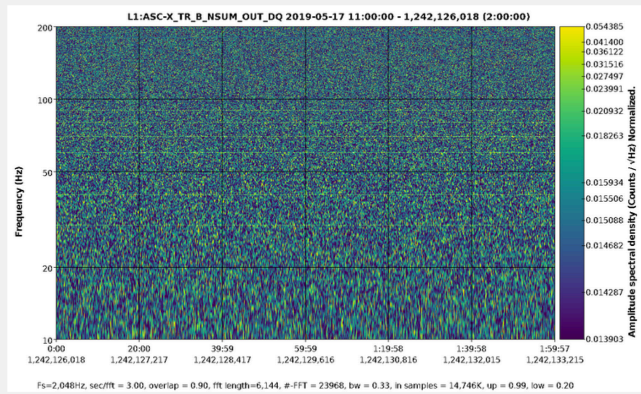
Was there early Nov!

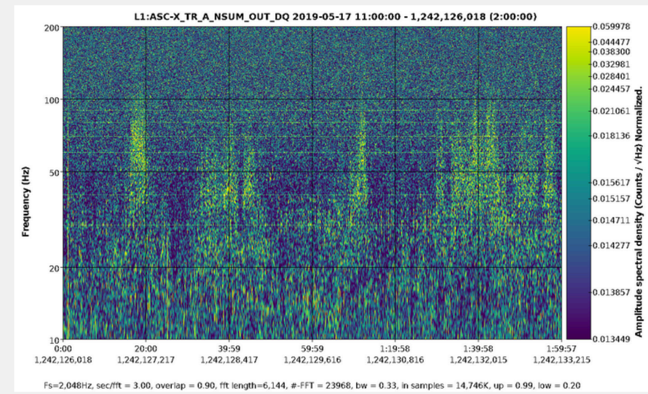


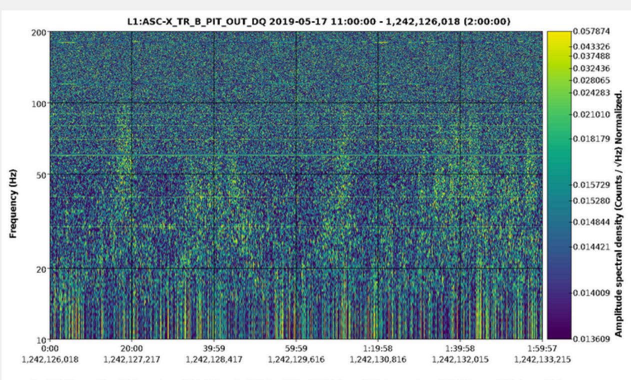






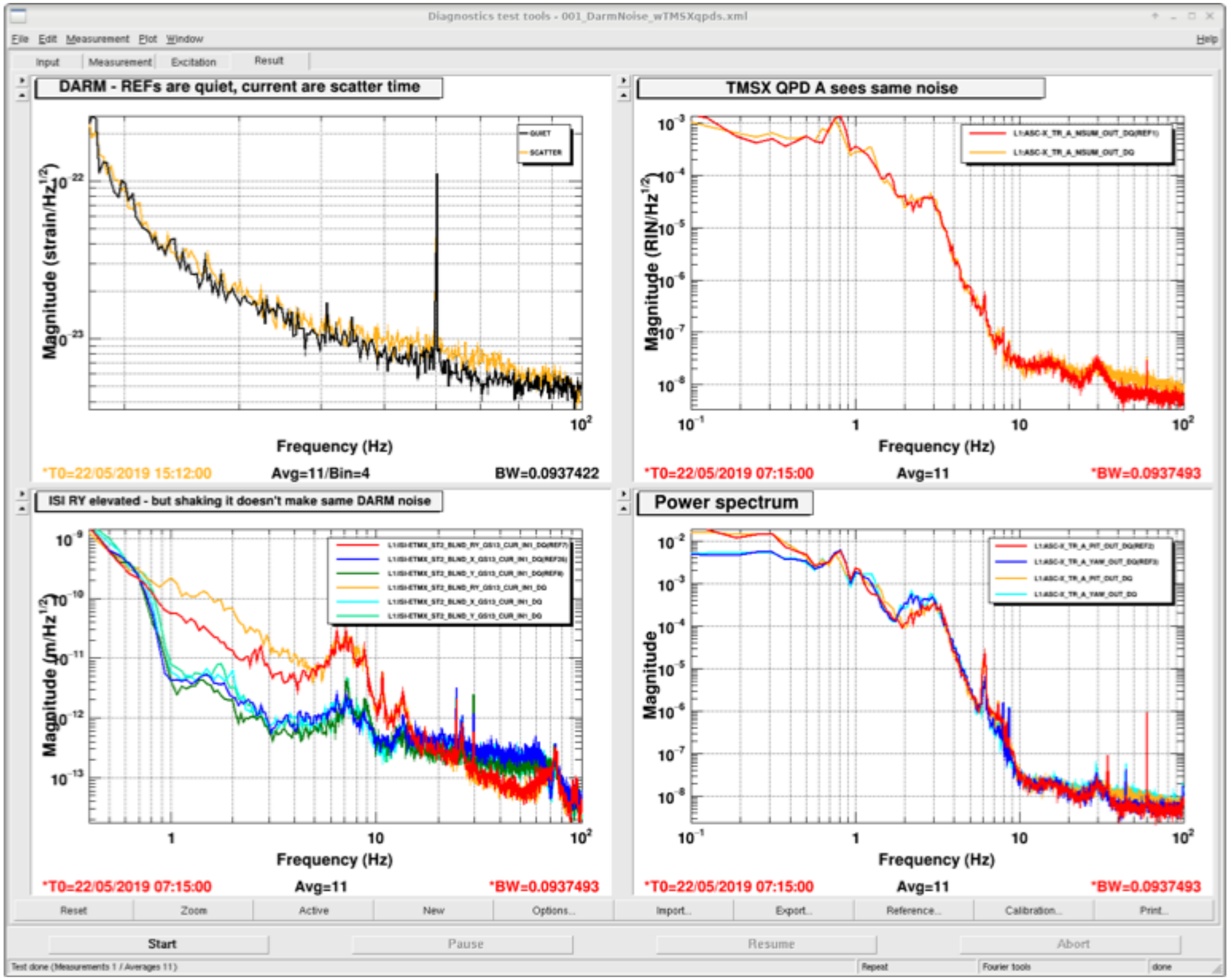




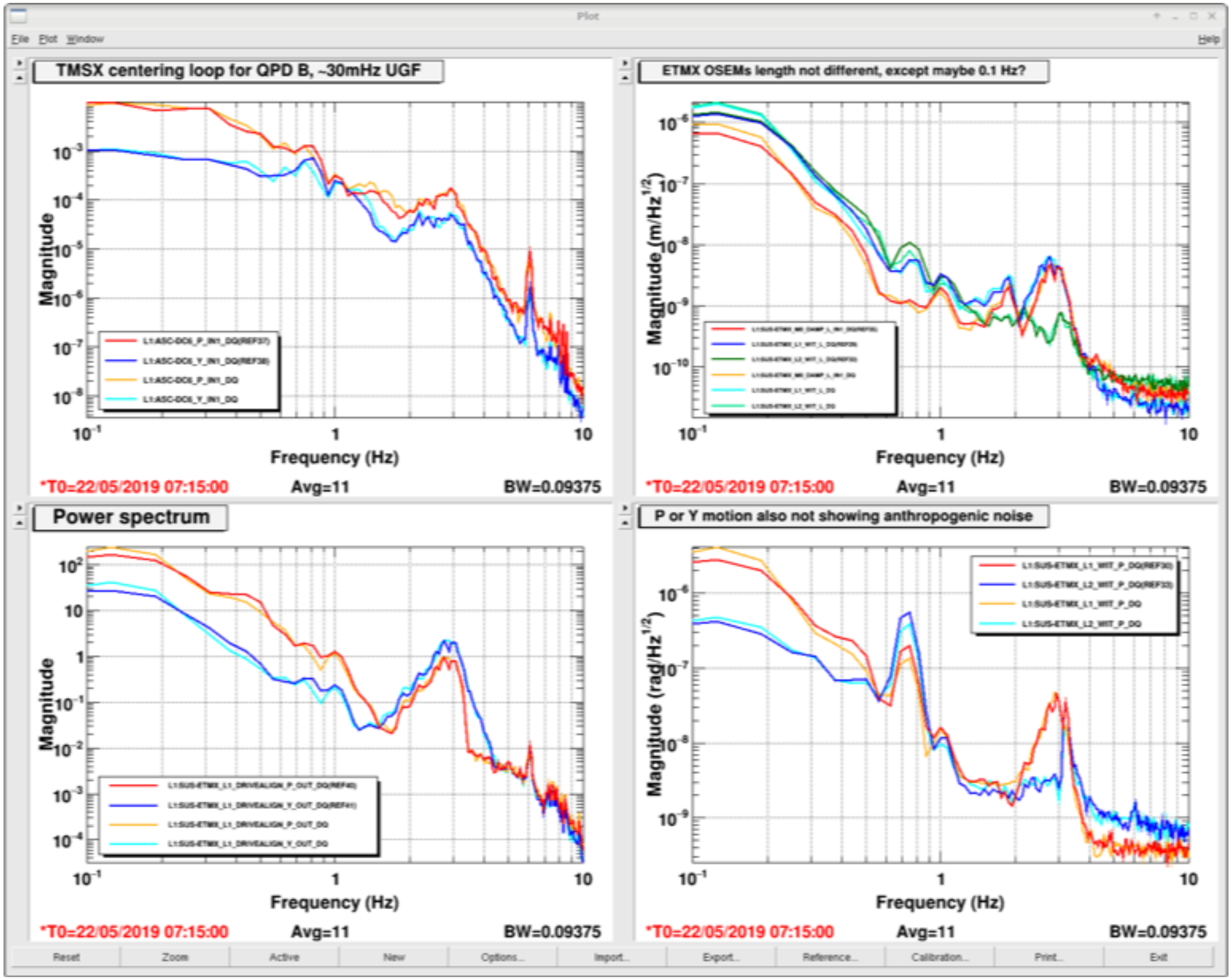


Why does X TR-B NSUM not see the noise?

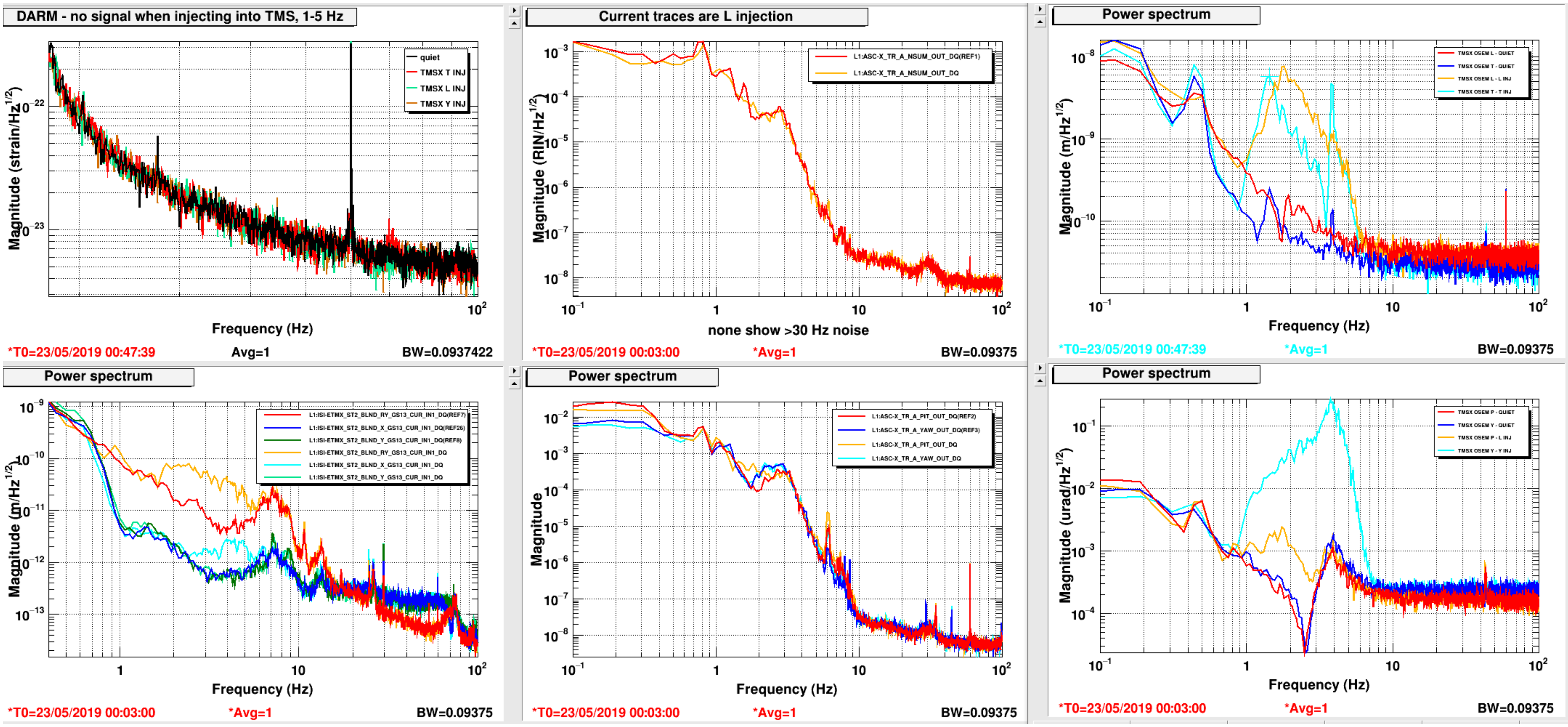
Spectral look



Not seen in drive signals



TMS 1-5 Hz injections don't reproduce noise



Neither does ISI or wall injection – except maybe a sweep we have to redo

Introduction

A. Vibration coupling

- **1) Worst site: LLO EX transmission monitor**
- **2) Next worst sites at LLO are EY and HAM5/6 and, at LHO, HAM5/6 and the PSL**
- **3) At both sites, HAM5/6 coupling is likely at the septum**
- **4) EY coupling at LLO is likely in the manifold, at LHO, it may in the ETMY chamber**
- **5) HAM5/6 coupling at the septum window?**
  - *Other beam spots on LLO HAM6*
  - *OMC REFL beam not the cause* of the main HAM5/6 scattering
  - *HAM6 witness search at LLO*
- **6) IO jitter coupling at both sites**
- **7) Comparison of EY and EX in-lock photos**
- **8) Shaker injections at EY produce noise similar to some anthropogenic noise**
- **9) Other vibration coupling**
  - *Beamtube shaking*
  - *Coupling at LHO BS chamber and at the reduction flanges by the optical lever*
  - *48 Hz peak at LHO*
  - *Reduction of 58 Hz chiller peak at LHO*:
- **10) Vibration coupling not seen (at least 10 below DARM)**
- **11) Coupling estimates from PEM injections correctly predict environmental coupling**
  - *LLO DARM glitch near S190510g* is correctly predicted from PEM injection coupling functions.
  - *Range reduction from LHO HVAC* is roughly predicted from estimates for HAM5/6.
  - *Range reduction from rain* at LHO is roughly consistent with PEM coupling functions
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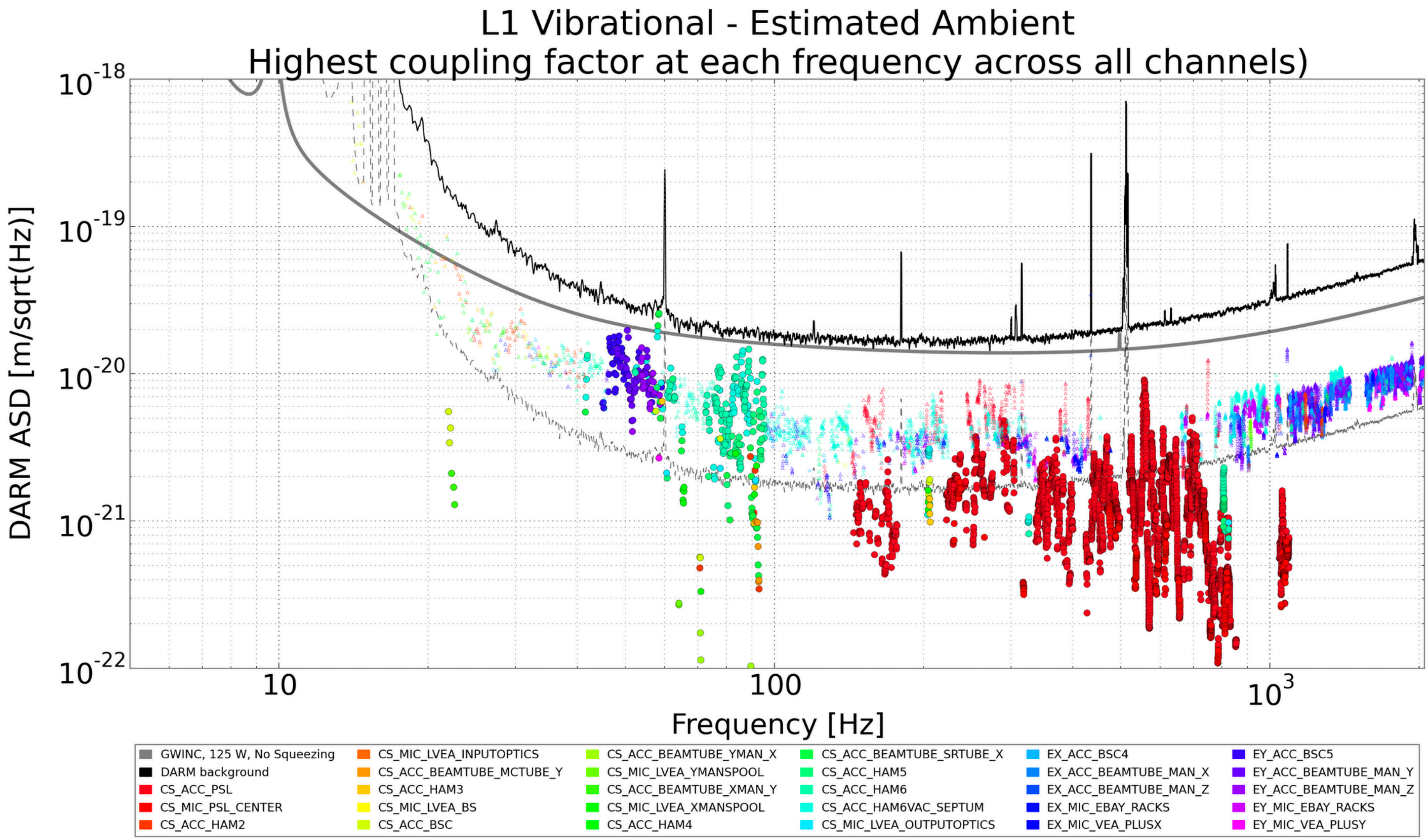
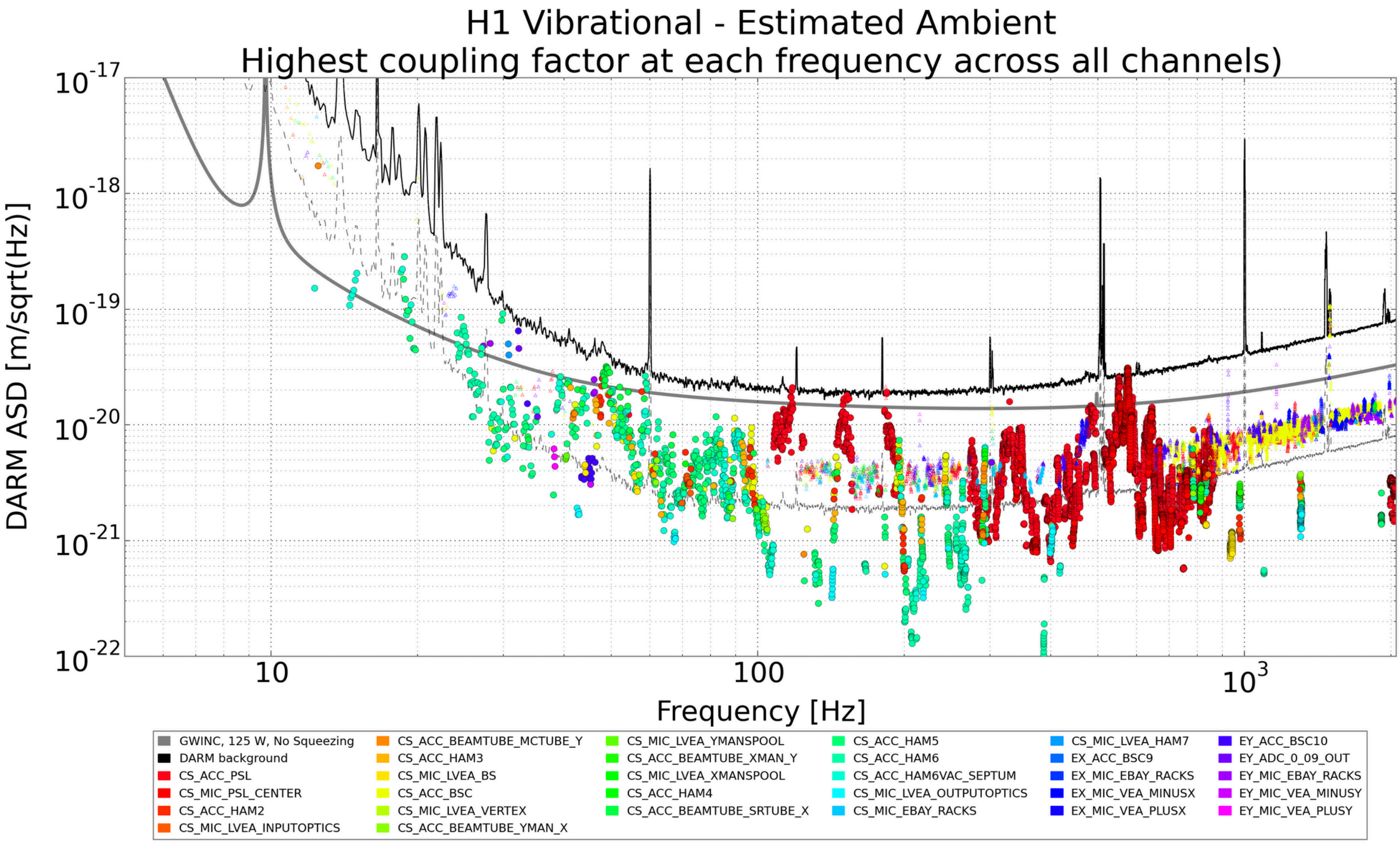
C. RF Coupling

D. Site activities



Ambient estimates are made by multiplying coupling factors by injection-free sensor levels. CIRCLES indicate estimates from measured coupling factors, i.e. where the injection signal was seen in the sensor and in DARM. TRIANGLES represent upper limit coupling factors, i.e. where a signal was seen in the sensor but not in DARM. For some channels, at certain frequencies the ambient estimates are upper limits because the ambient level is below the sensor noise floor.



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B. Magnetic Coupling

C. RF Coupling

D. Site activities

H1 PEM (DetChar) Link

robert.schofield@LIGO.ORG - posted 17:32, Tuesday 30 April 2019 (48886)

Impulse injection techniques point towards septum as being main source of HAM5/6 scattering at LLO and at LHO

Sharan Banagiri, Corey Austin, Philippe Nguyen, Anamaria Effler, Robert Schofield

Summary: For impulse injections from multiple locations, signals from accelerometers mounted on the HAM5/6 septum are the best match to DARM in arrival time, have the most consistent amplitude ratios with DARM, and have the most similar frequency structure to the effect of the impulse in DARM. Together with shaking data, this suggests that the septum is the dominant vibration coupling site in the LVEA at both sites. These vacuum enclosure impulse techniques promise to be a useful new tool for diagnosing scattering noise.

Shaking injections made throughout the corner station have shown, in recent PEM injections, as well as for some time before that, that above a few Hz, motion of the vacuum enclosure couples most strongly to DARM in the HAM5/6 area of both LHO and LLO. We have had trouble narrowing down the coupling site further using the shaking amplitude technique because the HAM5/6 region is relatively small and interconnected (if you shake one side of HAM5, the opposite side of HAM6 moves almost as much).

Impulse injection delays

To provide extra information, we investigated the use of impulse propagation delays to help identify coupling sites. In the past, we have narrowed down coupling sites by looking for the microphone that detects an acoustic impulse at about the same time that the signal appears in DARM. And, of course, we have tapped on the vacuum enclosure. But we hadn't tried using propagation delays from impacts on the vacuum enclosure to accelerometers mounted on the enclosure. While the vacuum enclosure is made of steel, the propagation velocity of waves on the steel membrane and structure is much lower than the velocity for bulk steel, resulting in tens of millisecond delays for propagation between HAM5 and 6.

Figures 1 and 2 show, for LHO and LLO respectively, examples of impulse injection data. These and other injections indicate that vacuum enclosure impulses show up in DARM about the same time as it shows up on the septum accelerometer.

The down side to the impulse timing technique is that higher frequencies are needed in order to discriminate arrival times (here we have used a 70-200 Hz band). Thus, there is the danger that a coupling site that dominates at low frequencies is not the dominant site at high frequencies. However, we have checked bands at lower frequencies and not seen obvious differences and results from two other impulse-based techniques are consistent.

Impulse injection amplitudes

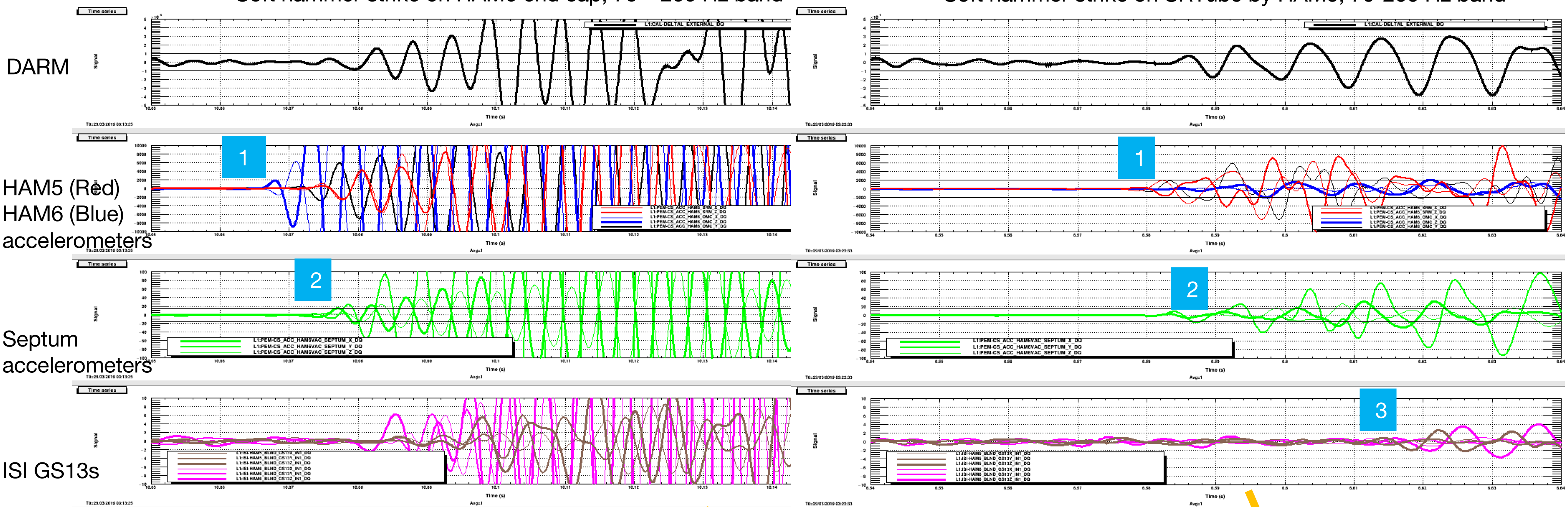
In addition to arrival timing, we also used the amplitude of the prompt impulse vs. the amplitude of the prompt signal in DARM to discriminate coupling locations. The examples in Figures 1 and 2 show that the amplitude in DARM is most consistent with the amplitude of the signal on the septum accelerometer. An advantage of the impulse technique over our usual shaking is that there appears to be a greater difference in amplitude between accelerometers on HAM5 and those on HAM6 for an impulse injection than for a steady state injection. This may be because, for the steady state, the many late reflections have built up the amplitude to nearly the same at all locations in the region (in equilibrium, the energy gets distributed more evenly).

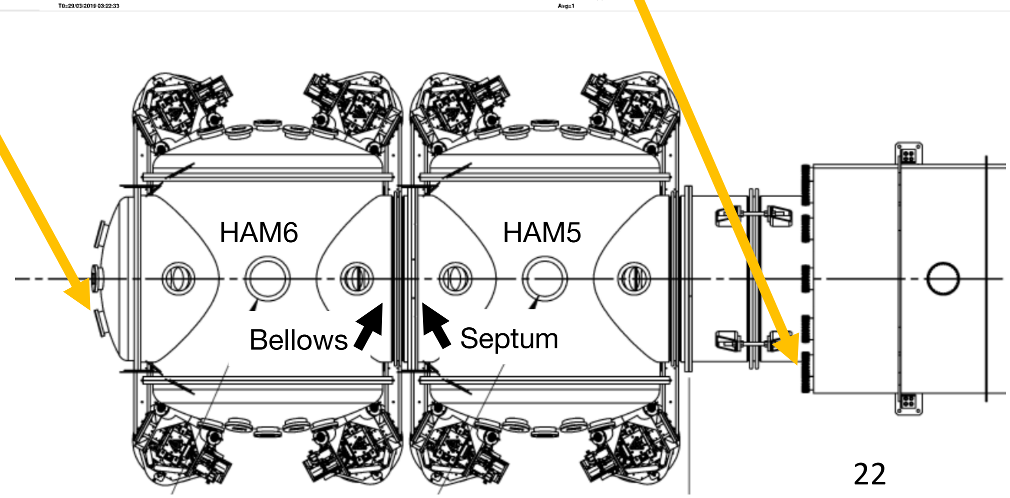
Impulse injection frequency content

Figure 1a. L1 coupling time and amplitude consistent with septum or HAM5 walls, not HAM6 walls or ISI tables

Soft hammer strike on HAM6 end cap, 70 – 200 Hz band

Soft hammer strike on SRTube by HAM5, 70-200 Hz band



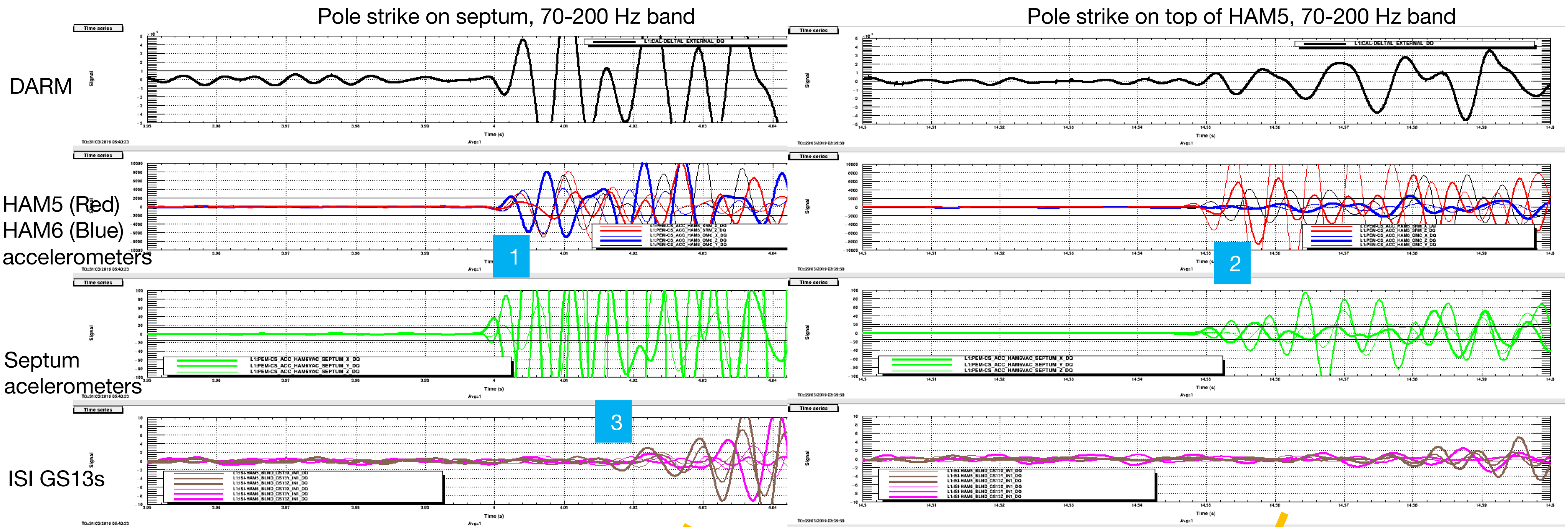


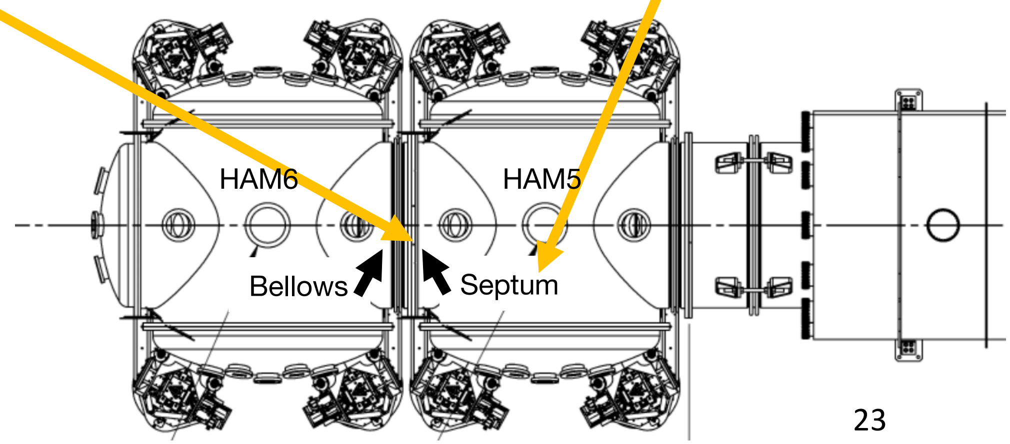
1. Blue HAM 6 accelerometers are not consistent in amplitude or time with effect in DARM, while HAM5 and septum accelerometers are.

2. For example, DARM (top trace) crosses 1 about the same time as The green septum accelerometers cross 15 for these and other impulses.

3. Late arrival of signal on ISI GS13s indicates that the effect in DARM is associated with the vacuum enclosure, not motion of table.

Figure 1b. L1 coupling amplitude is most consistent with septum, not other monitored parts of HAM5



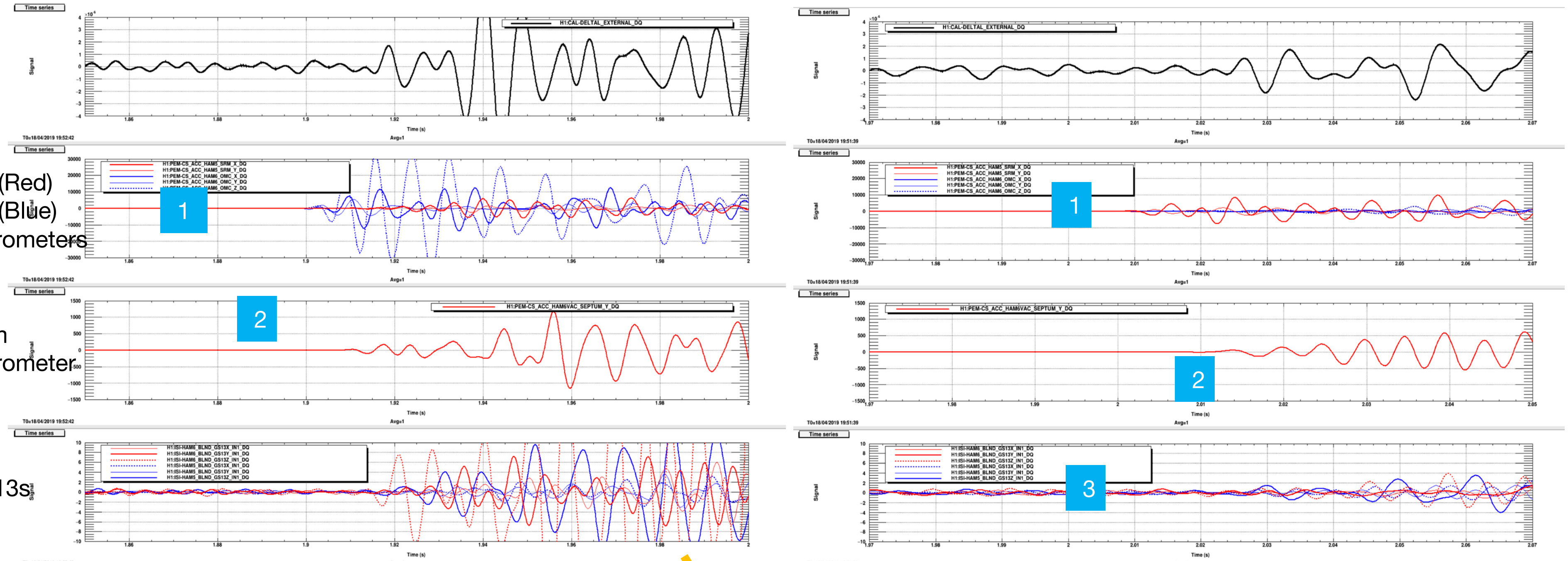


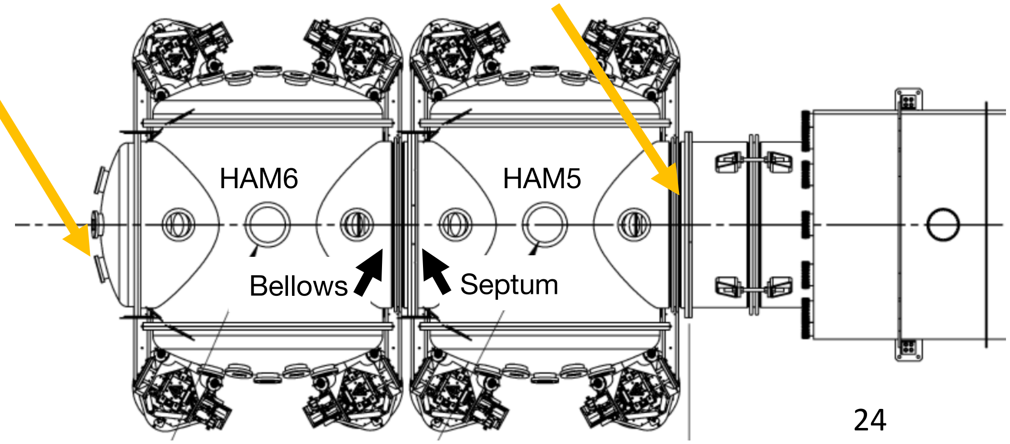
1 2 Green septum accelerometers are consistent with signal size in DARM but red HAM5 accelerometer signals are bigger for the impulse on the right than for the one on the left, while the DARM amplitude is the other way around.

3 Late arrival of signal on ISI GS13s indicates that the effect in DARM is associated with the vacuum enclosure, not motion of table.

Figure 2a. H1 coupling time and amplitude consistent with septum, not HAM5/6 walls or ISI tables

Pole strike on HAM6 end cap, 70 – 200 Hz band | Pole strike on HAM5 +Y flange, 70-200 Hz band



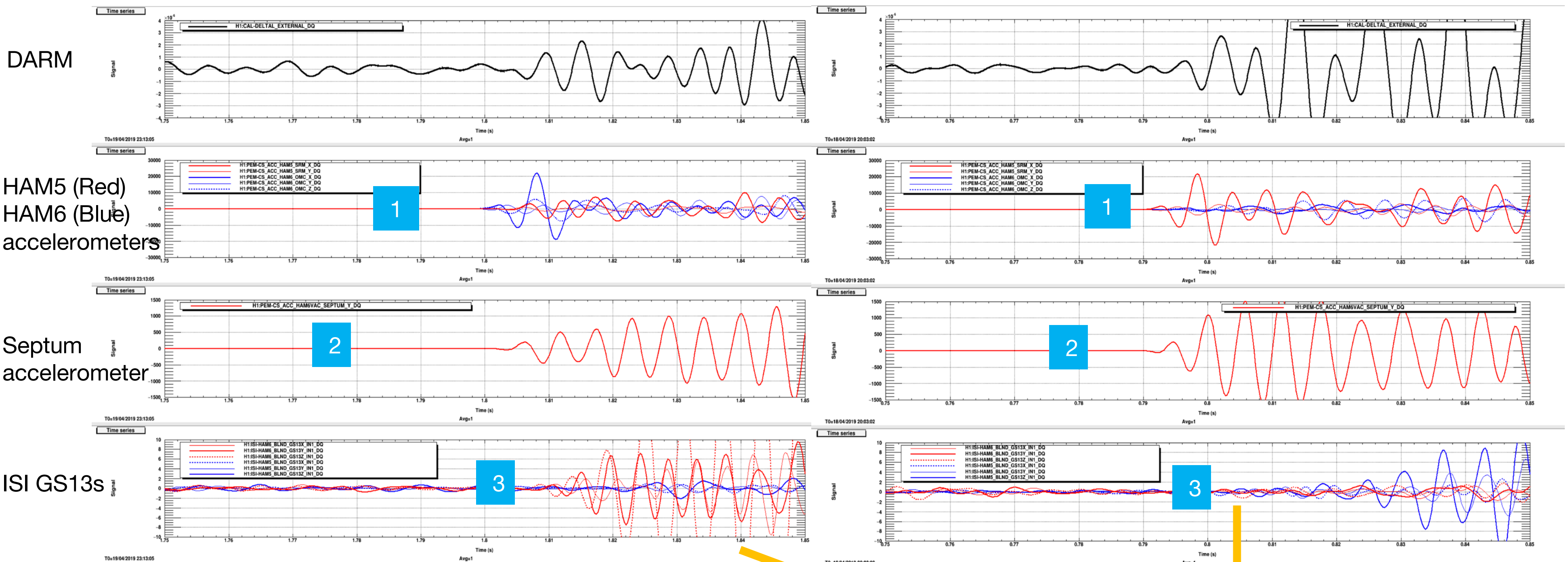


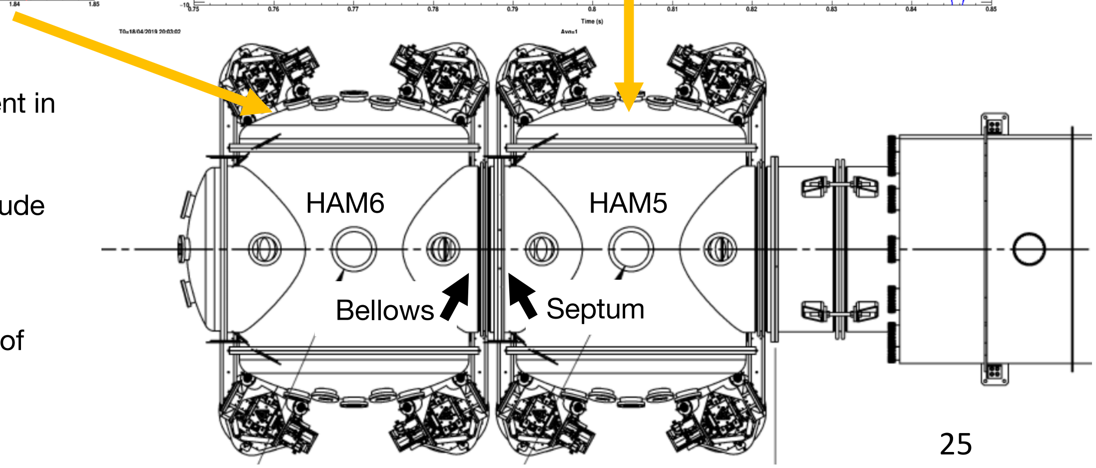
1. Blue HAM6 and red HAM5 accelerometers are not consistent in amplitude or time with effect in DARM
2. Septum accelerometer is more consistent in time and amplitude with DARM
3. Late arrival of signal on ISI GS13s indicates that the effect in DARM is associated with the vacuum enclosure, not motion of table.

Figure 2b. H1 coupling time and amplitude consistent with septum, not HAM5/6 walls or ISI tables

Pole strike on HAM6 -X door, 70 – 200 Hz band

Pole strike on HAM5 -X door, 70-200 Hz band

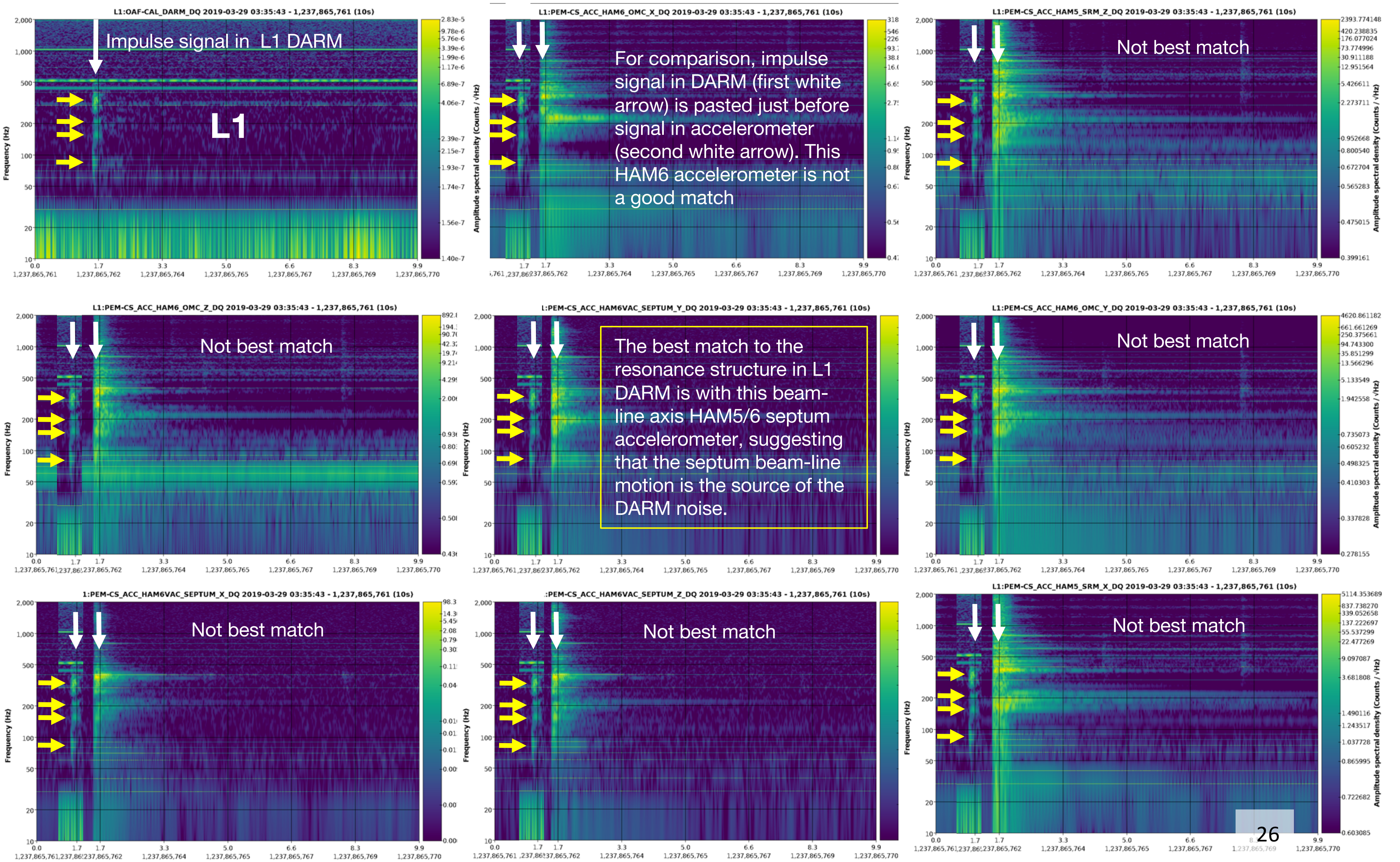


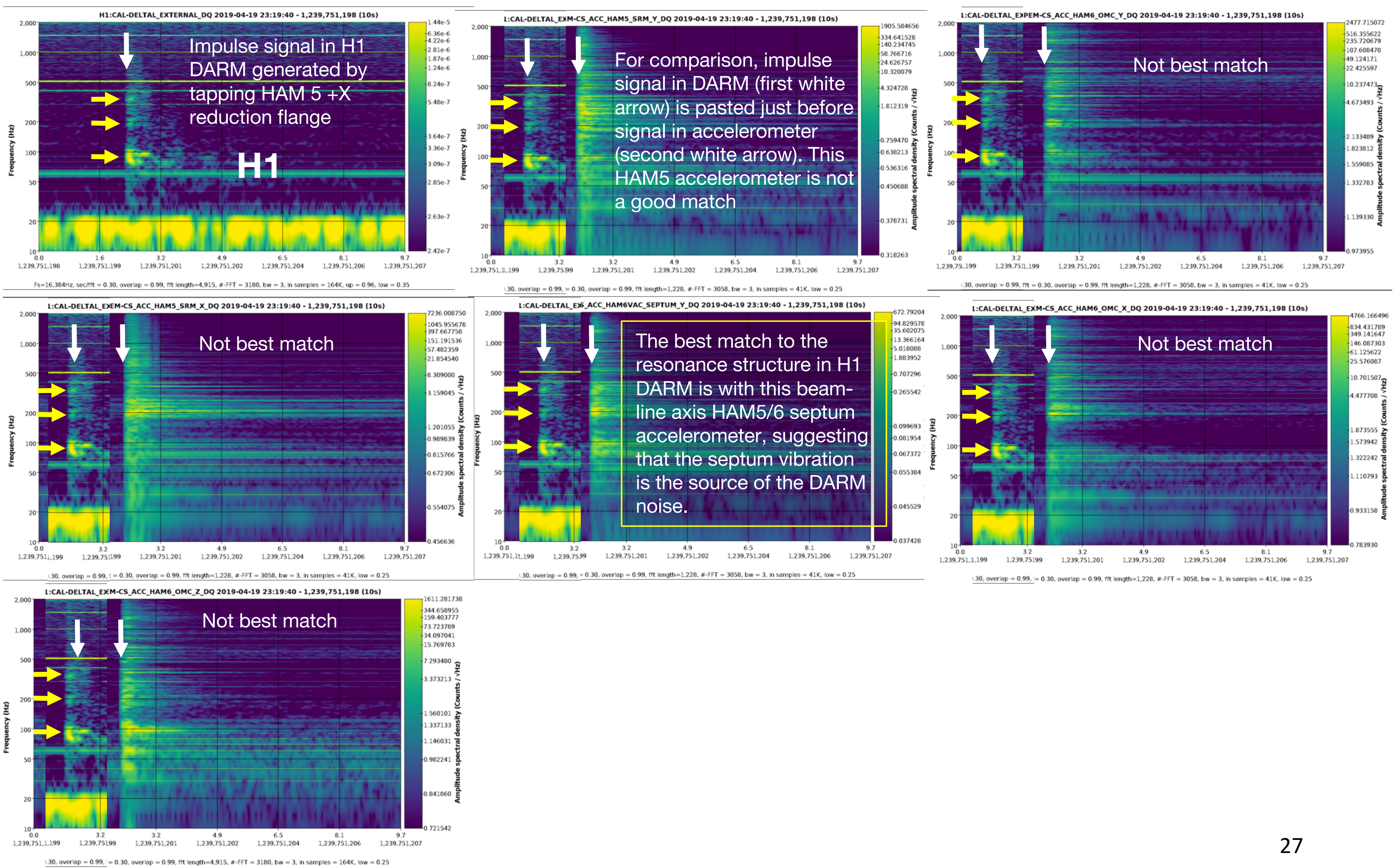


1 Blue HAM 6, and red HAM5 accelerometers are not consistent in amplitude or time with effect in DARM.

2 Septum accelerometer is more consistent in time and amplitude with DARM

3 Late arrival of signal on ISI GS13s indicates that the effect in DARM is associated with the vacuum enclosure, not motion of table.


L1:OAF-CAL_DARM_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
Impulse signal in L1 DARM
L1
L1:PEM-CS_ACC_HAM6_OMC_X_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
For comparison, impulse signal in DARM (first white arrow) is pasted just before signal in accelerometer (second white arrow). This HAM6 accelerometer is not a good match
L1:PEM-CS_ACC_HAM5_SRM_Z_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
Not best match
L1:PEM-CS_ACC_HAM6_OMC_Z_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
Not best match
L1:PEM-CS_ACC_HAM6VAC_SEPTUM_Y_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
The best match to the resonance structure in L1 DARM is with this beam-line axis HAM5/6 septum accelerometer, suggesting that the septum beam-line motion is the source of the DARM noise.
L1:PEM-CS_ACC_HAM6_OMC_Y_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
Not best match
1:PEM-CS_ACC_HAM6VAC_SEPTUM_X_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
Not best match
:PEM-CS_ACC_HAM6VAC_SEPTUM_Z_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
Not best match
L1:PEM-CS_ACC_HAM5_SRM_X_DQ 2019-03-29 03:35:43 - 1,237,865,761 (10s)
Not best match
Frequency (Hz)
Amplitude spectral density (Counts / √Hz)



H1:CAL-DELTAL_EXTERNAL_DQ 2019-04-19 23:19:40 - 1,239,751,198 (10s)
Impulse signal in H1 DARM generated by tapping HAM 5 +X reduction flange
H1
L:CAL-DELTAL_EXM-CS_ACC_HAM5_SRM_Y_DQ 2019-04-19 23:19:40 - 1,239,751,198 (10s)
For comparison, impulse signal in DARM (first white arrow) is pasted just before signal in accelerometer (second white arrow). This HAM5 accelerometer is not a good match
L:CAL-DELTAL_EXPEM-CS_ACC_HAM6_OMC_Y_DQ 2019-04-19 23:19:40 - 1,239,751,198 (10s)
Not best match
L:CAL-DELTAL_EXEM-CS_ACC_HAM5_SRM_X_DQ 2019-04-19 23:19:40 - 1,239,751,198 (10s)
Not best match
L:CAL-DELTAL_EX6_ACC_HAM6VAC_SEPTUM_Y_DQ 2019-04-19 23:19:40 - 1,239,751,198 (10s)
The best match to the resonance structure in H1 DARM is with this beam-line axis HAM5/6 septum accelerometer, suggesting that the septum vibration is the source of the DARM noise.
L:CAL-DELTAL_EXM-CS_ACC_HAM6_OMC_X_DQ 2019-04-19 23:19:40 - 1,239,751,198 (10s)
Not best match
L:CAL-DELTAL_EXM-CS_ACC_HAM6_OMC_Z_DQ 2019-04-19 23:19:40 - 1,239,751,198 (10s)
Not best match
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3) At both sites, HAM5/6 coupling is likely at the septum

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Other beam spots on LLO HAM6

OMC REFL beam not the cause of the main HAM5/6 scattering

HAM6 witness search at LLO

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Beamtube shaking

Coupling at LHO BS chamber and at the reduction flanges by the optical lever

48 Hz peak at LHO

Reduction of 58 Hz chiller peak at LHO:

10) Vibration coupling not seen (at least 10 below DARM)

11) Coupling estimates from PEM injections correctly predict environmental coupling

LLO DARM glitch near S190510g is correctly predicted from PEM injection coupling functions.

Range reduction from LHO HVAC is roughly predicted from estimates for HAM5/6.

Range reduction from rain at LHO is roughly consistent with PEM coupling functions

Range reduction from wind at LHO is roughly consistent with PEM coupling functions.

B. Magnetic Coupling

C. RF Coupling

D. Site activities

Reports until 19:55, Saturday 25 May 2019

L1 PEM (Detchar) Link

robert.schofield@LIGO.ORG - posted 19:55, Saturday 25 May 2019 (46208)

Impulse injections suggest that EY vibration coupling is, at LLO, near the Pcal periscope and, at LHO, possibly in BSC10.

Philippe Nguyen, Sharan Banagiri, Corey Austin, Anamaria Effler, Robert Schofield

Summary: impulse injections suggest that the vibration coupling site at LLO EY is in the manifold (near the Pcal periscope) and, with less certainty, that the coupling site at LHO EY is in BSC 10. Resonance structure of the signals suggest that accelerometers were not mounted on the coupling sites. We discuss the limited evidence that baffling the rest of the Pcal periscope and installing nozzle baffles will mitigate the coupling at LLO EY.

The worst environmental coupling sites are, at LLO, associated with the EX transmission monitor (https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=46147) and after that, the HAM5/6 area, and EY. At LHO, HAM5/6, the PSL and EY are the worst vibration coupling sites.

At both LLO and LHO, impulse injections have narrowed the HAM5/6 vibration coupling sites to the septum (https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=48886). The impulse injections were made from multiple locations and, out of the array of accelerometers in the HAM5/6 area, the Y-axis septum accelerometer signal was most consistent with DARM in arrival time and amplitude for impulses from different directions, and in resonance structure.

We also made impulse injections at EY at both sites in order to narrow down the coupling sites.

Figure 1 shows examples of EY impulse injections at LLO suggesting that the timing and especially the amplitude of the signals are consistent with coupling in the manifold but not the BSC chamber.

Figure 2 shows that, for LHO, the case is most consistent with coupling, not at the manifold, but the BSC chamber itself.

Figure 3 shows the spectral structure of impulses at both sites. DARM has a different spectral fingerprint than any of the accelerometers (unlike the case for HAM5/6 injections). Without the matching resonance structure, the confidence level is lower for the EY sites than for the septum site.

A candidate structure in the manifold at LLO EY is, of course, the Pcal periscope. Figure 4 shows beam spot views of the Pcal periscope at the LLO EY location (that has been causing noise in DARM), and at the 2 LHO locations. The LLO EY location has a fairly bright retro-reflection from the inner back surface, indicated by yellow arrows. The "glint" is ranked about as high as the reduction flanges near the ITM

Figure 1a. <u>LLO EY</u>: accelerometer signals are consistent with manifold coupling but not coupling at the BSC

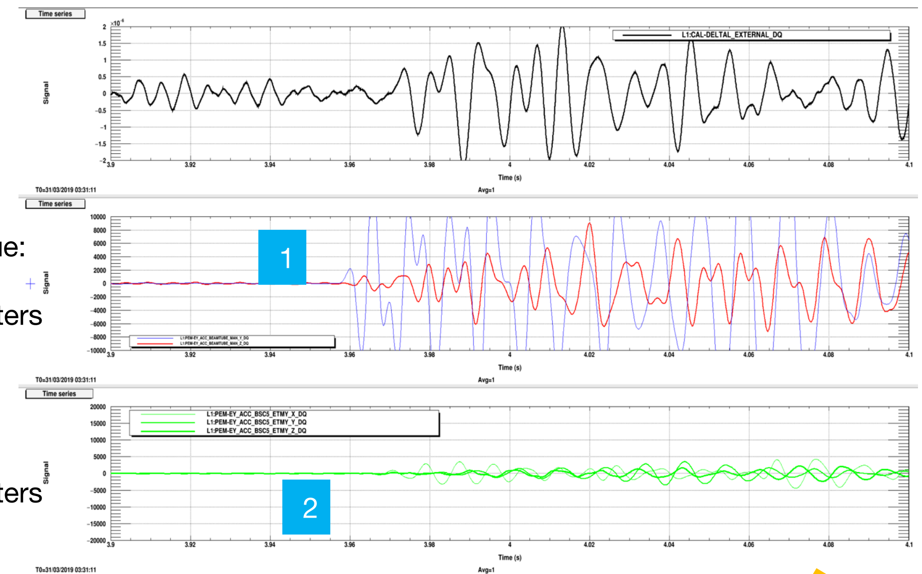
Soft hammer strike on GV 10, 70-200 Hz band

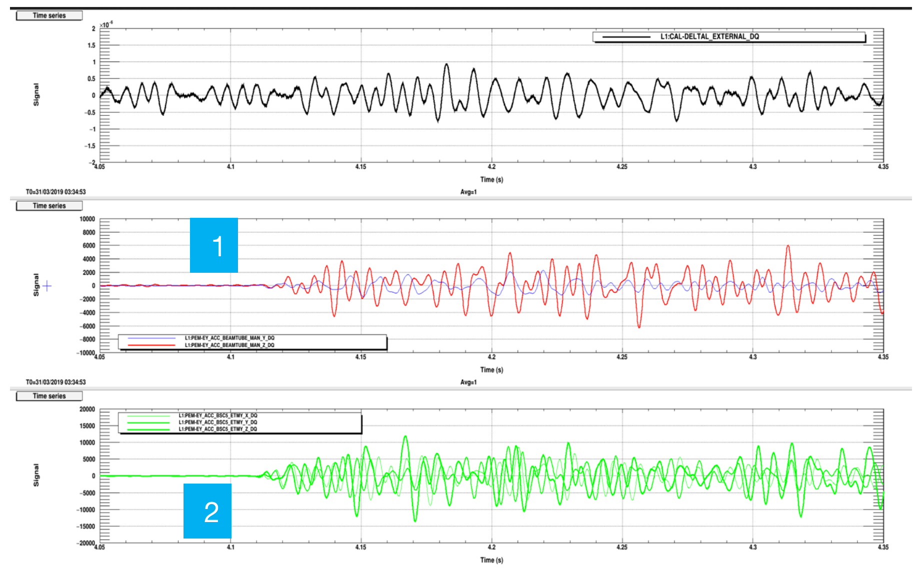
Soft hammer strike on underside of BSC5, 70-200 Hz band

DARM

Red and Blue: manifold accelerometers

BSC 5 accelerometers





1 DARM time and amplitude are consistent with red and blue manifold accelerometers: DARM crosses 1 about the same time red or blue cross 8000 for these and other impulses

2 Green BSC chamber accelerometers are not consistent in time or amplitude with DARM signal

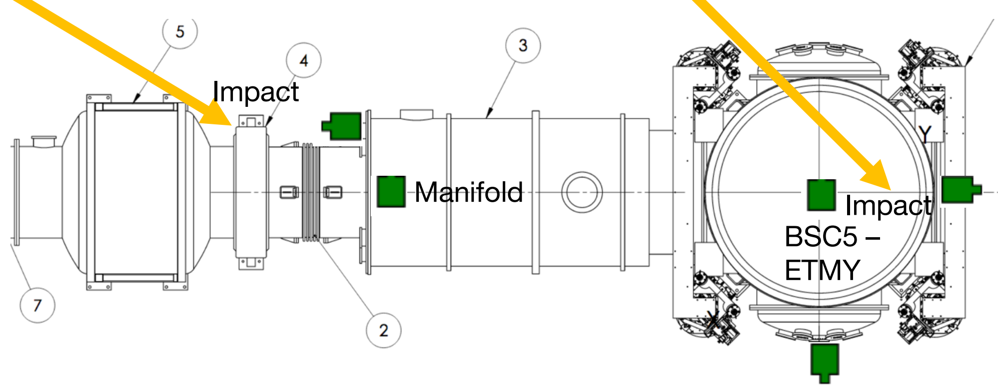


Figure 1b. LLO EY: accelerometer signals are most consistent with coupling site in manifold

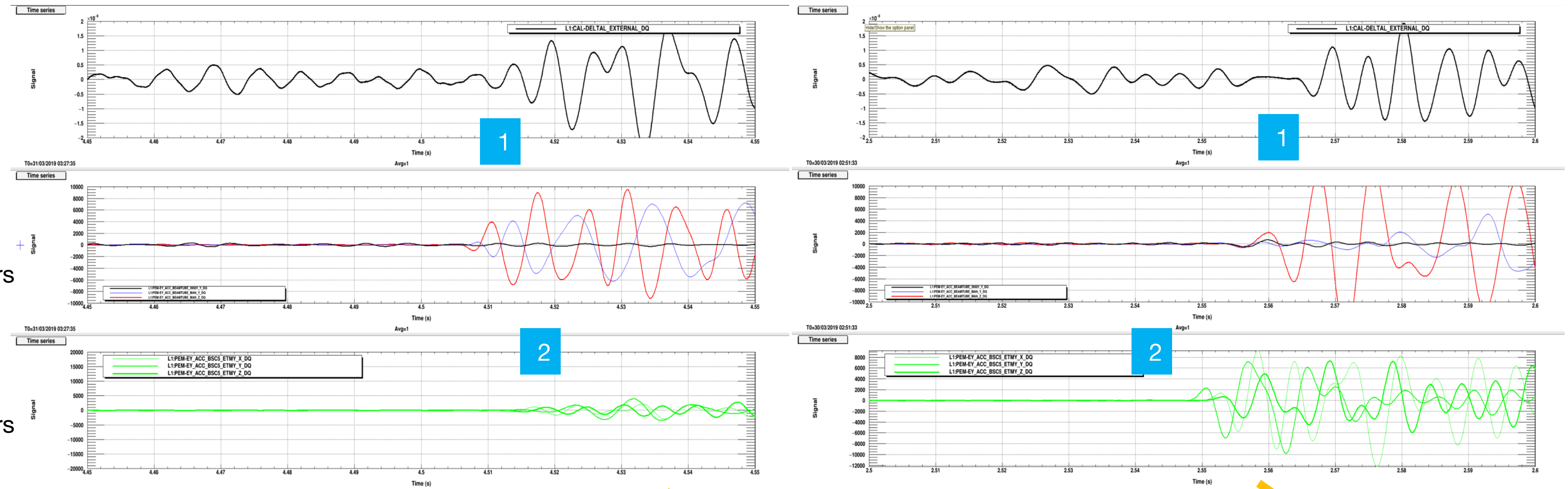
Soft hammer strike on -Y reduction flange, 70-200 Hz band

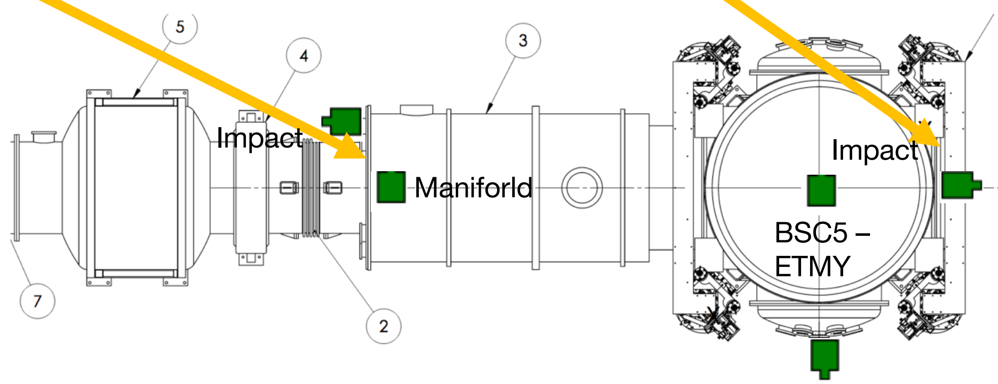
Soft hammer strike on end cap, 70-200 Hz band

DARM

Red and Blue: manifold accelerometers

BSC 5 accelerometers





1 DARM time and amplitude are consistent with red and blue manifold accelerometers: DARM crosses 1 about the same time red or blue cross 8000 for these and other impulses

2 Green BSC chamber accelerometers are not consistent in time or amplitude with DARM signal

Figure 2a. LHO EY: accelerometer signals are consistent with BSC coupling but not coupling at the manifold

Pole strike on BSC6 end cap

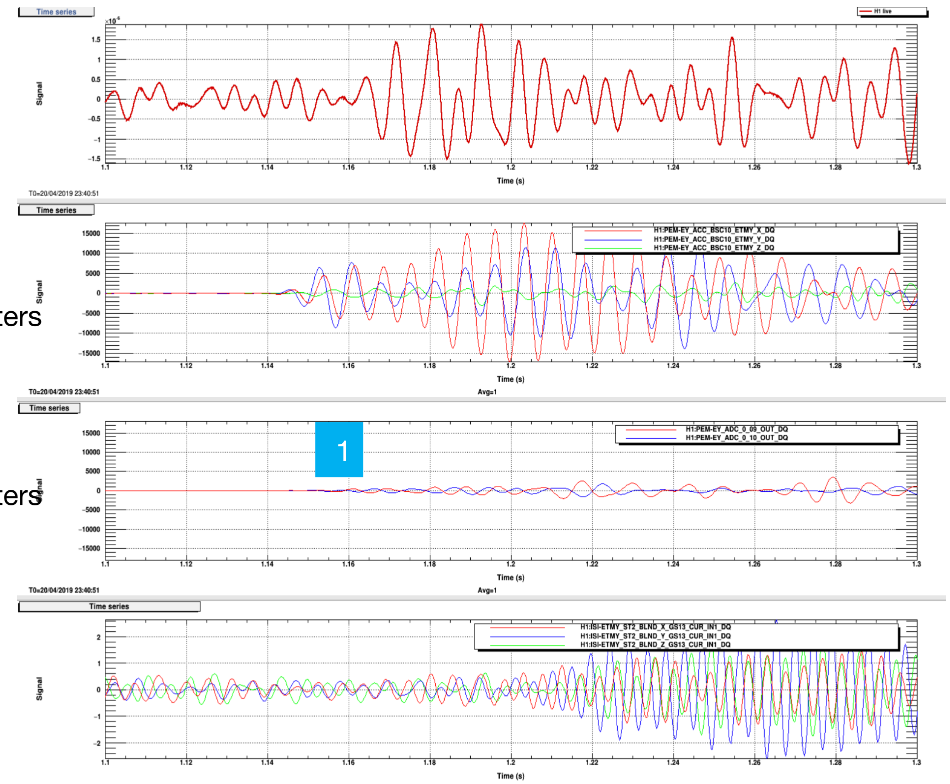
Pole strike on gate valve

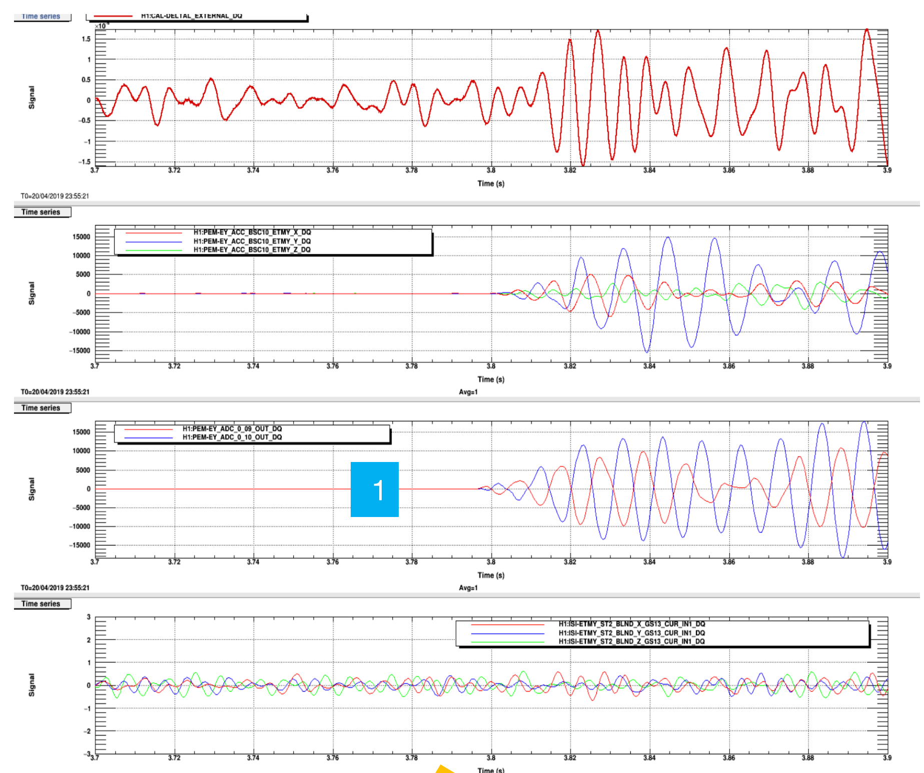
DARM

BSC5 accelerometers

Manifold accelerometers

ISI table GS 13s





1 The amplitude of the manifold accelerometers are not consistent with the amplitude in DARM

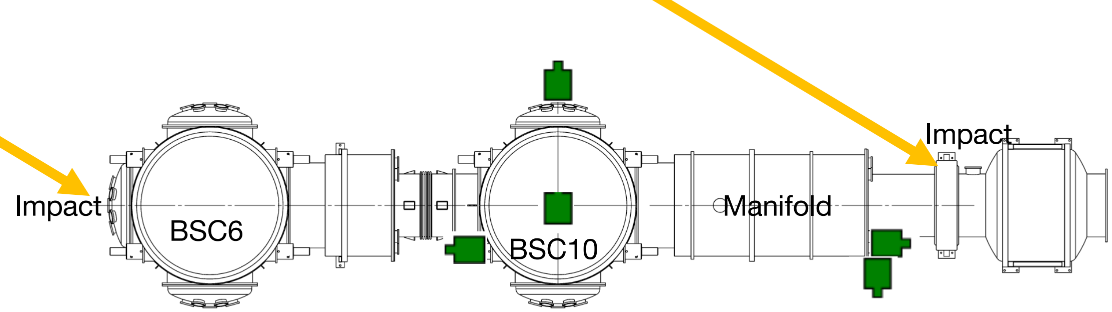
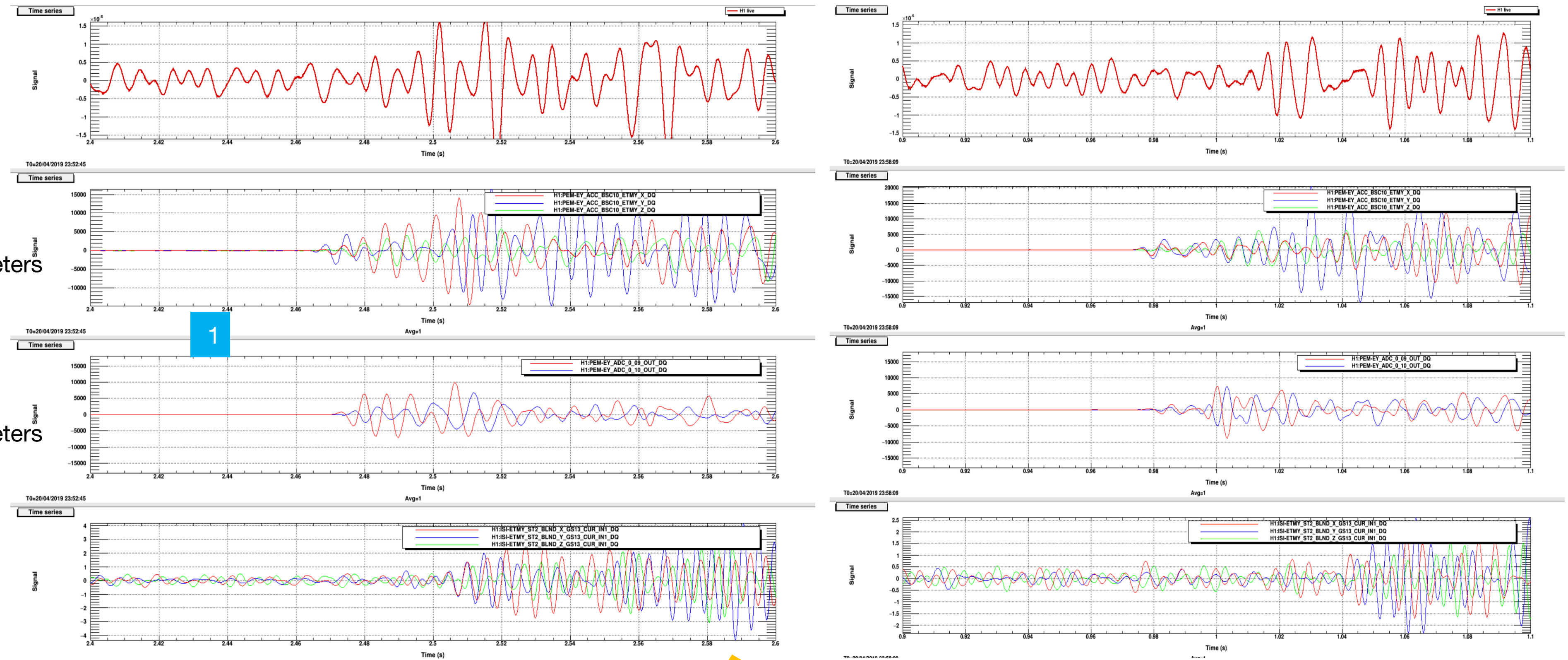
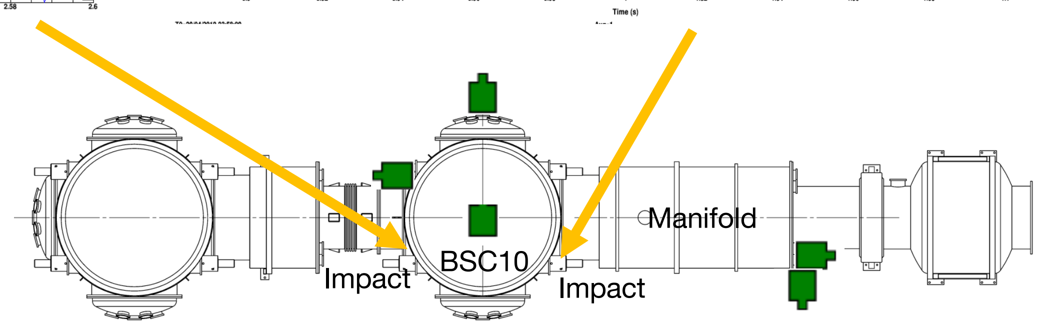


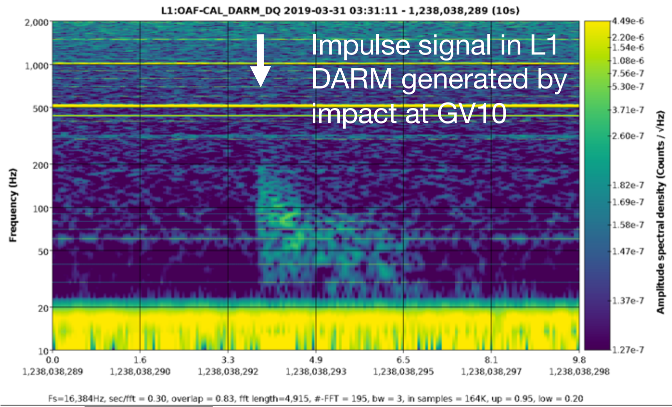
Figure 2b. LHO EY: accelerometer signals are consistent with BSC coupling

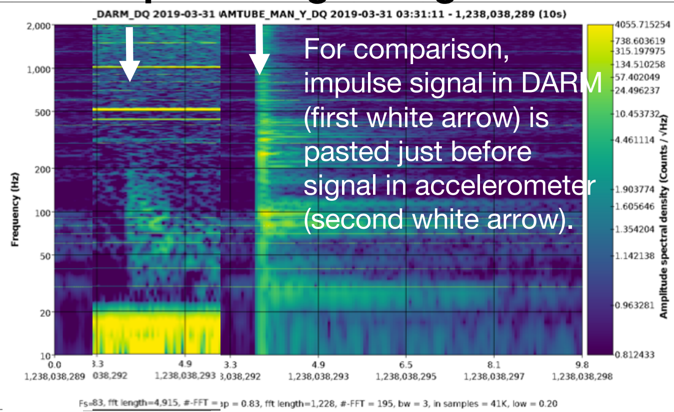


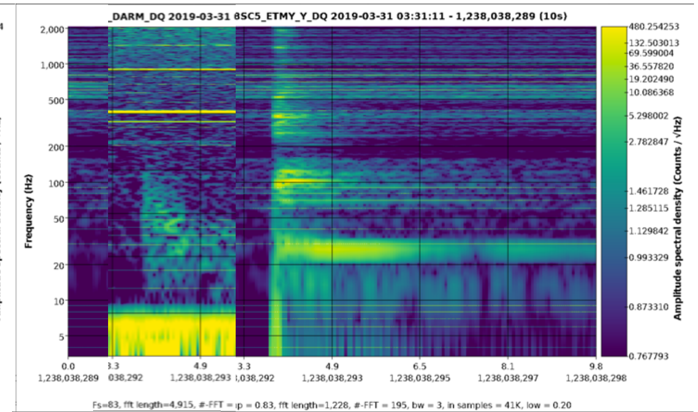


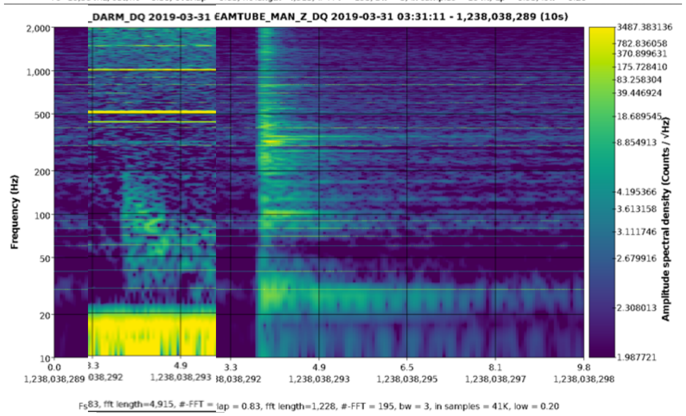
1 BSC5 accelerometers are slightly more consistent with DARM than manifold accelerometers

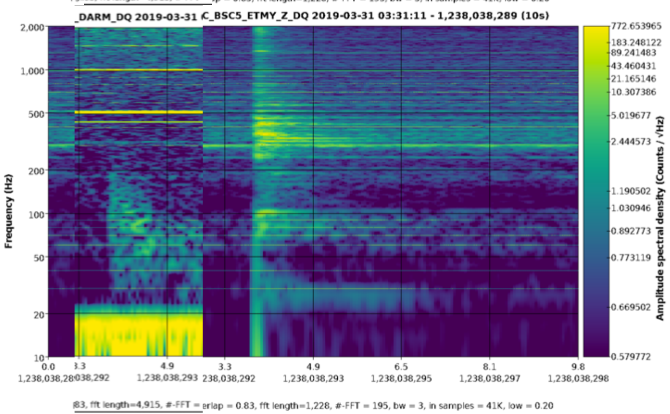
LLO EY Impulse originating at GV10

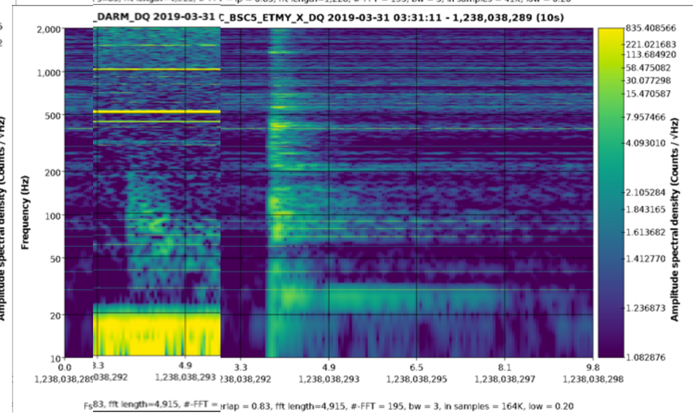


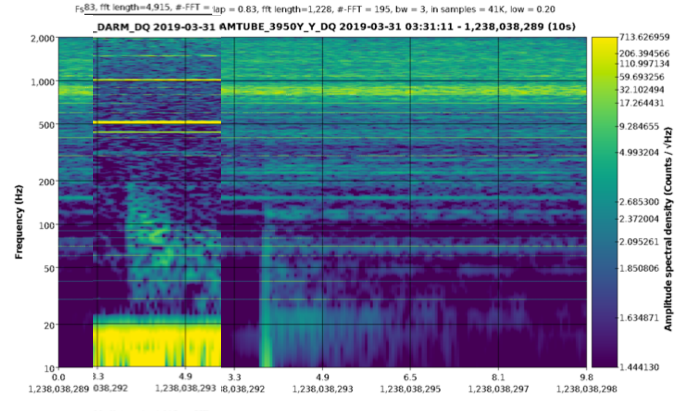






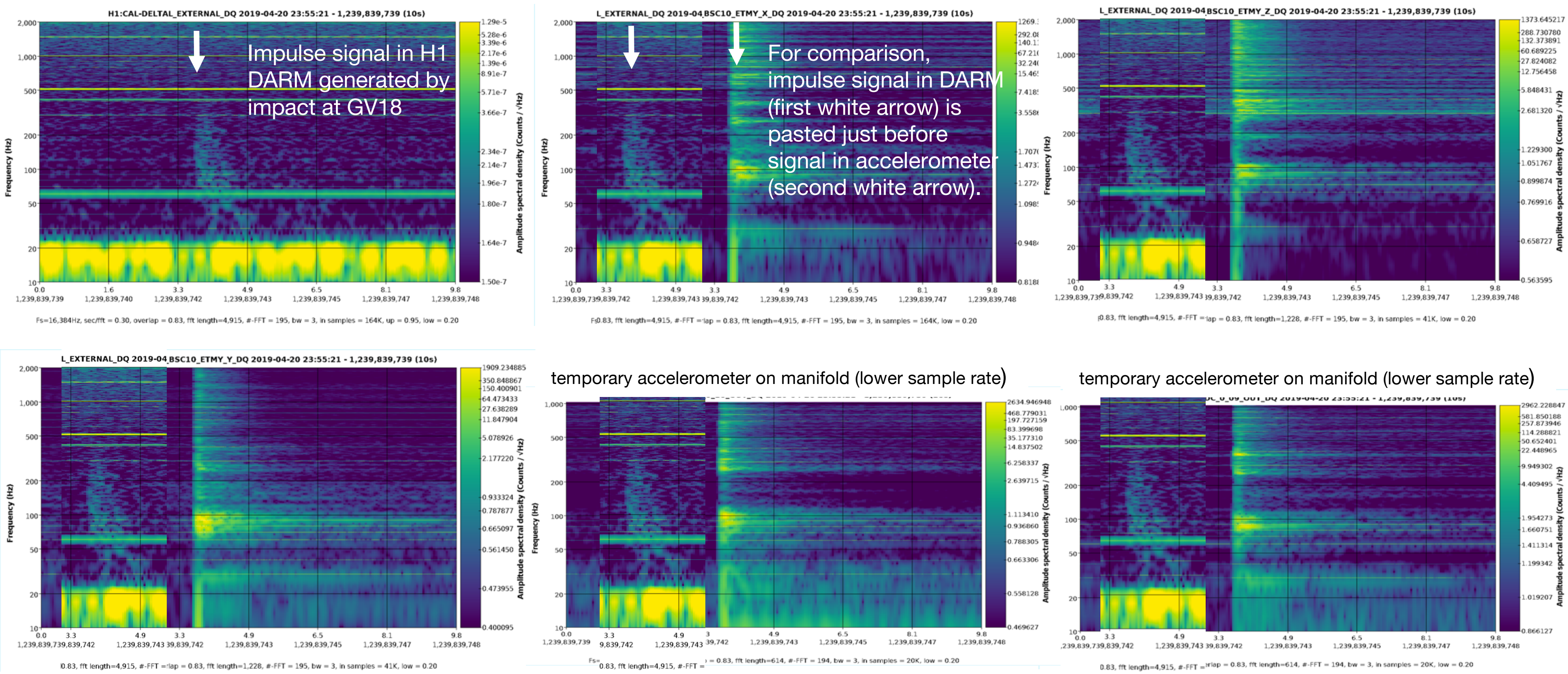






Lack of a match to DARM in frequency content suggests that no accelerometer is on coupling surface.

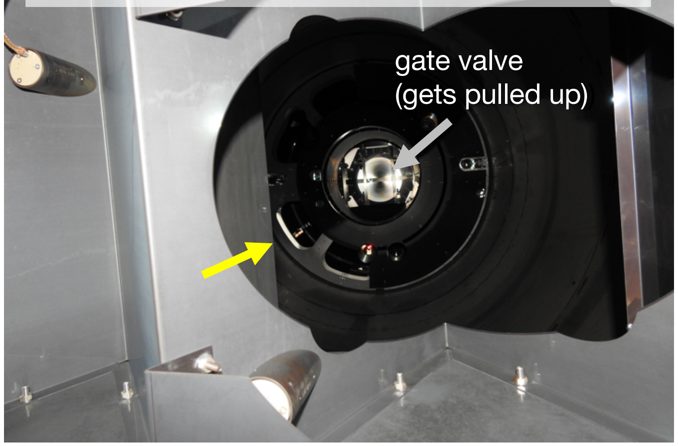
LHO EY Impulse originating at GV 18

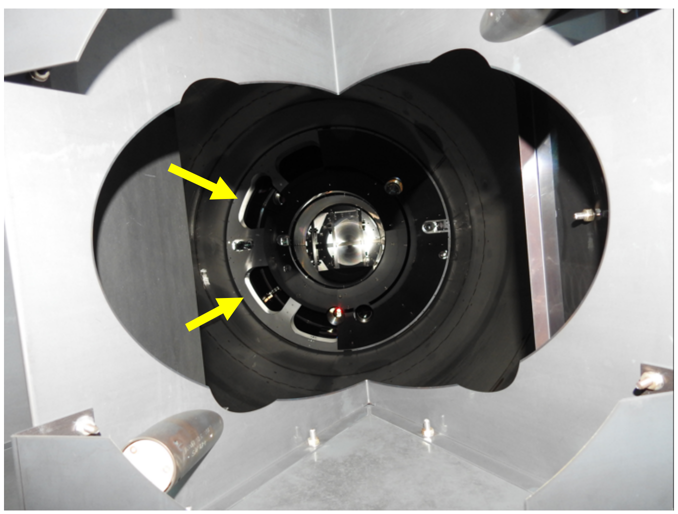


Lack of a match to DARM in frequency content suggests that no accelerometer is on coupling surface. Signal in DARM is slow at starting up, as if not tightly coupled to the vacuum enclosure wall.

LLO EY (2 views)

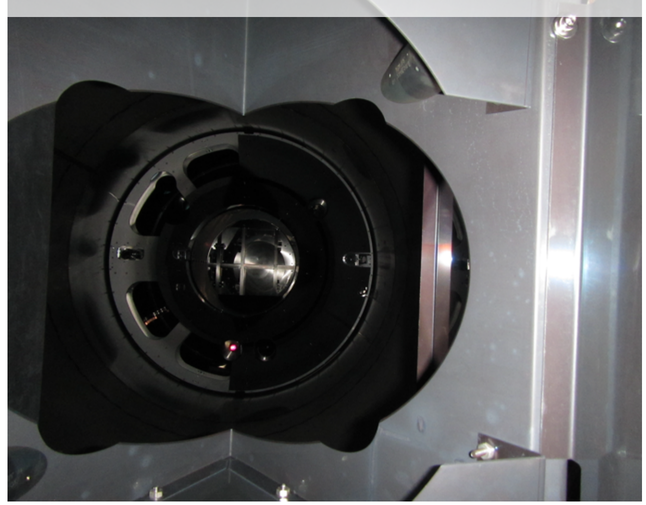
Fairly bright retroreflections from back ring of periscope at LLO-EY (yellow arrows)

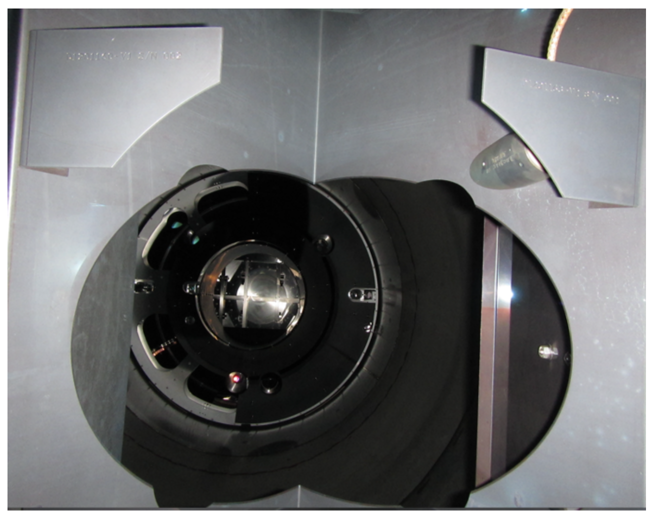




LHO EY (2 views)

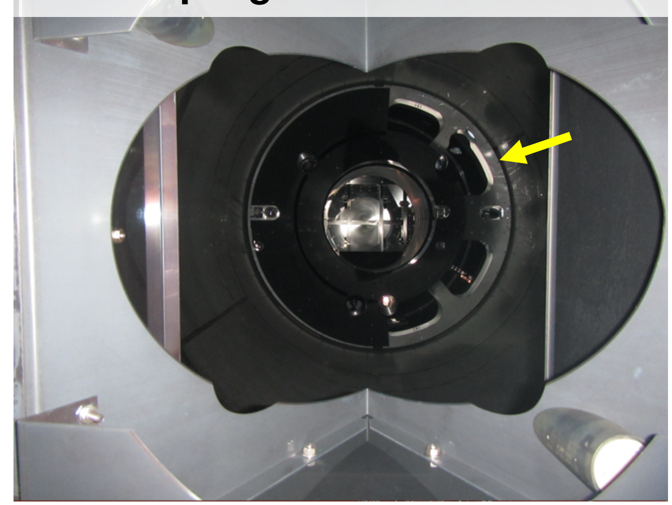
Similar glints can be seen at LHO EY

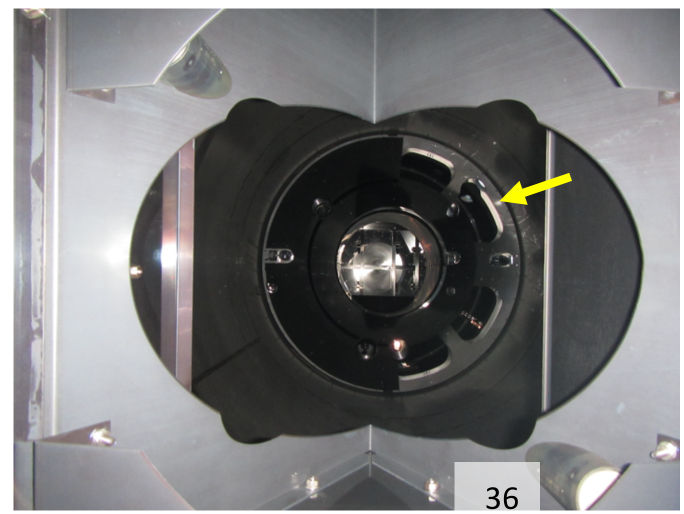




LHO EX (2 views)

LHO EX has similar glints, without the coupling to DARM.





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HAM6 witness search at LLO

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48 Hz peak at LHO

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Range reduction from wind at LHO is roughly consistent with PEM coupling functions.

B. Magnetic Coupling

C. RF Coupling

D. Site activities

H1 PEM (DetChar)

Link

robert.schofield@LIGO.ORG - posted 15:33, Friday 03 May 2019 (48965)

The brightest beam spot seen in inspection through HAM5/6 viewports appears to be ~3 degree scattering from the septum window.

Philippe, Sharon, Anamaria, Robert

We looked for stray light through the 5 viewports indicated on the first page of Figure 1. We saw stray light from the OFI, but, by far, the brightest light appeared to be from the septum window from the end-cap view. I could not see this bright spot from the viewports on HAM5 or the center viewport on the HAM6 endcap, only from the +X viewport on the HAM6 end cap. This view is not available at LLO. Figure 1a-c show photos, and detail the argument that the spot is forward-scattering, at 3-degrees, of light from the beam spot on the septum window. For example, the parallax photographs in Figure 1c are consistent with the origin being at the septum window. In addition, they show that the spot is bright over several inches at the viewport, and thus more likely to be diffuse scattering than a ghost beam.

We could not see all parts of the septum, but, except for the window, we did not see other spots on the septum (this was also the case for the parts of the septum we could see at LLO - https://alog.ligo-la.caltech.edu/aLOG/index.php?callRep=44985).

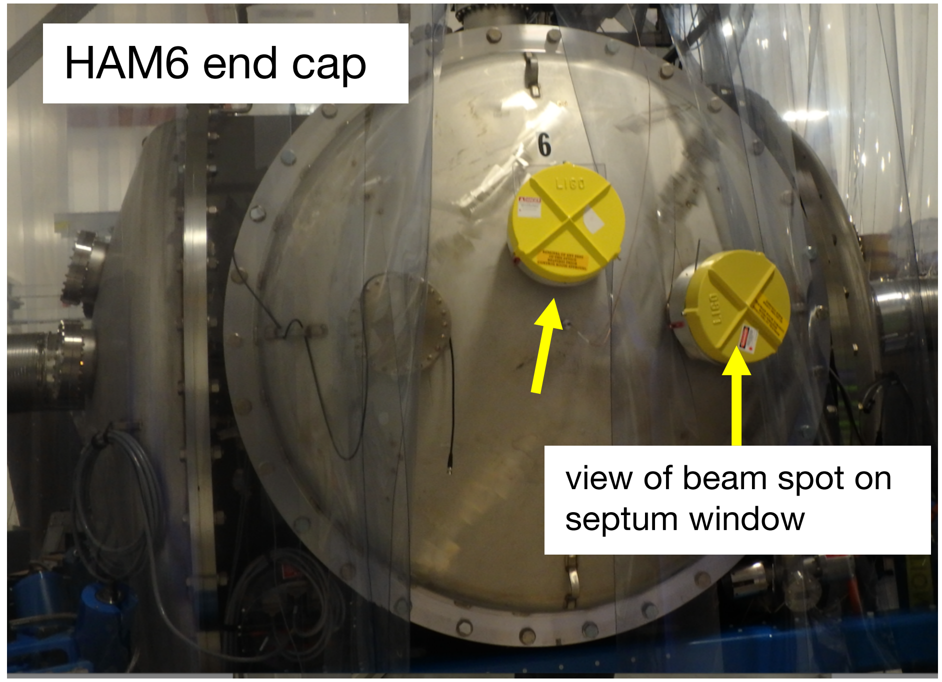
Impulse injections, along with shaker injections, suggest that the septum is the dominant scattering site, at least in the band above 20 Hz, at LHO and LLO: https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=48886. The noise produced by septum motion, estimated from PEM injection results, is consistent with the loss of range due the HVAC at LHO: https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=48912. The observation of bright scattering from the LHO window, but not from other examined regions of the septum at either site, is evidence that the septum window could be the scattering site on the septum.

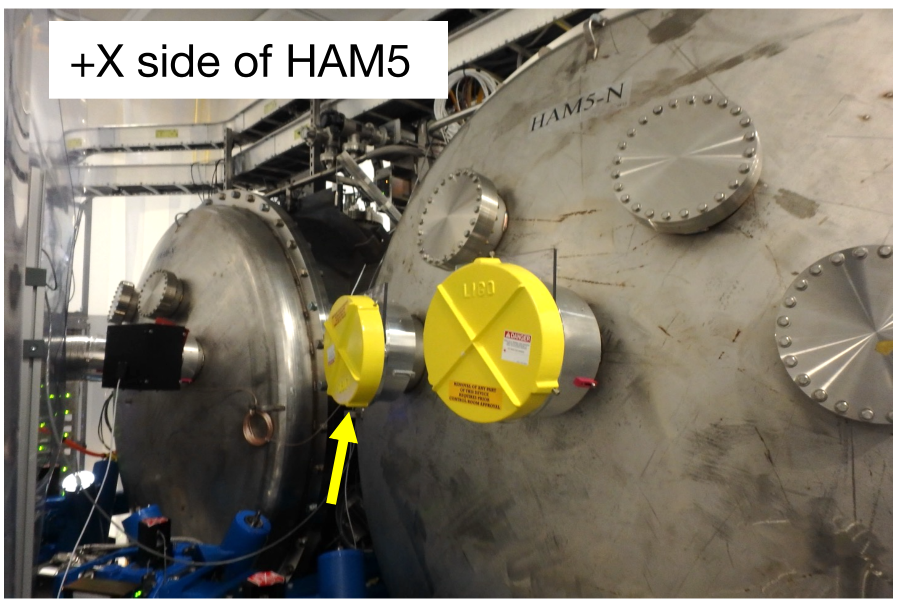
Figure 2 shows a plot from LIGO-T0900269-v2 that is a reminder that we expect scattering from the septum window to be close to limiting. This, along with the visual observation evidence and the evidence from the shaker and impulse injections, all accumulate to suggest that it may be time to consider removing the septum windows at both sites.

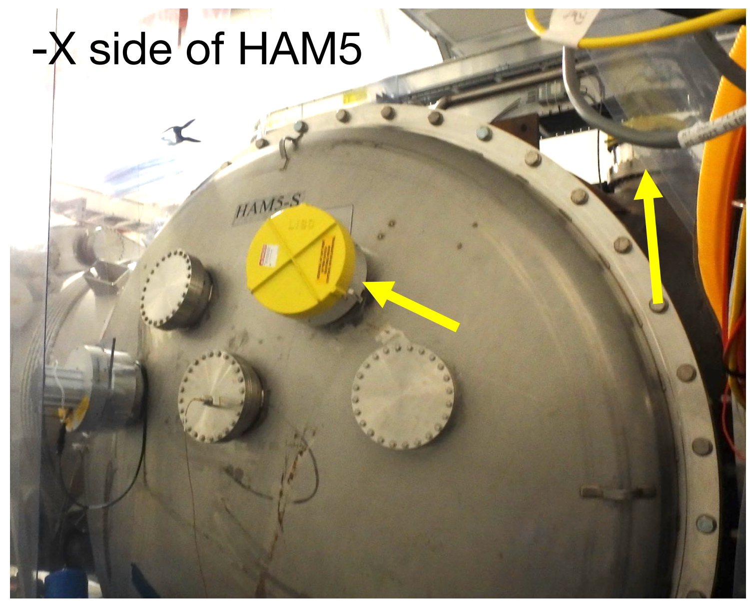
Non-image files attached to this report

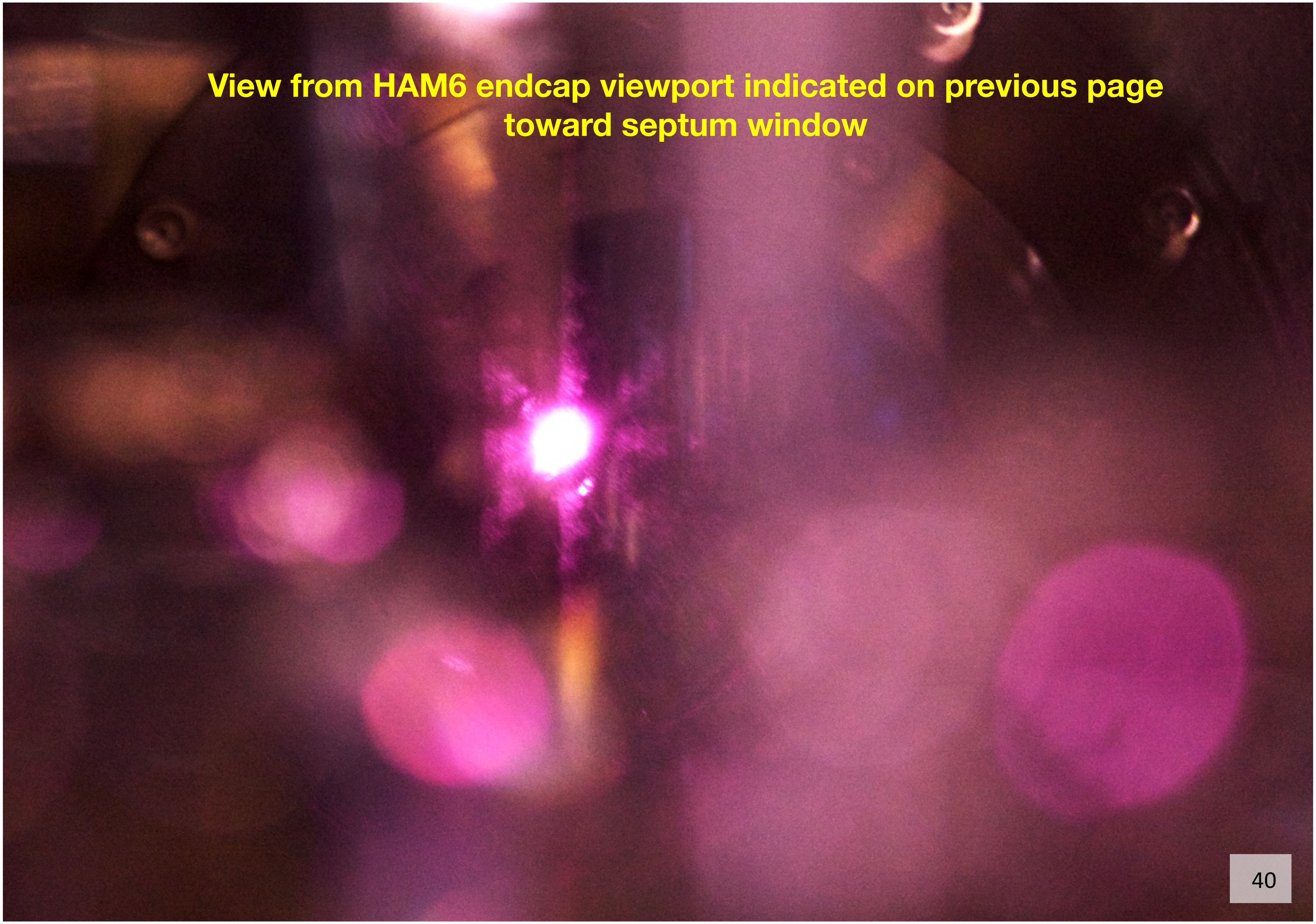
- Figure1a-Viewports-septum-window-spot.pdf
- Figure1b-Septum-window-spot-OM2pdf.pdf
- Figure1c-Septum-window-parallax-partial.pdf
- Figure2-Original-estimated-contribution.pdf

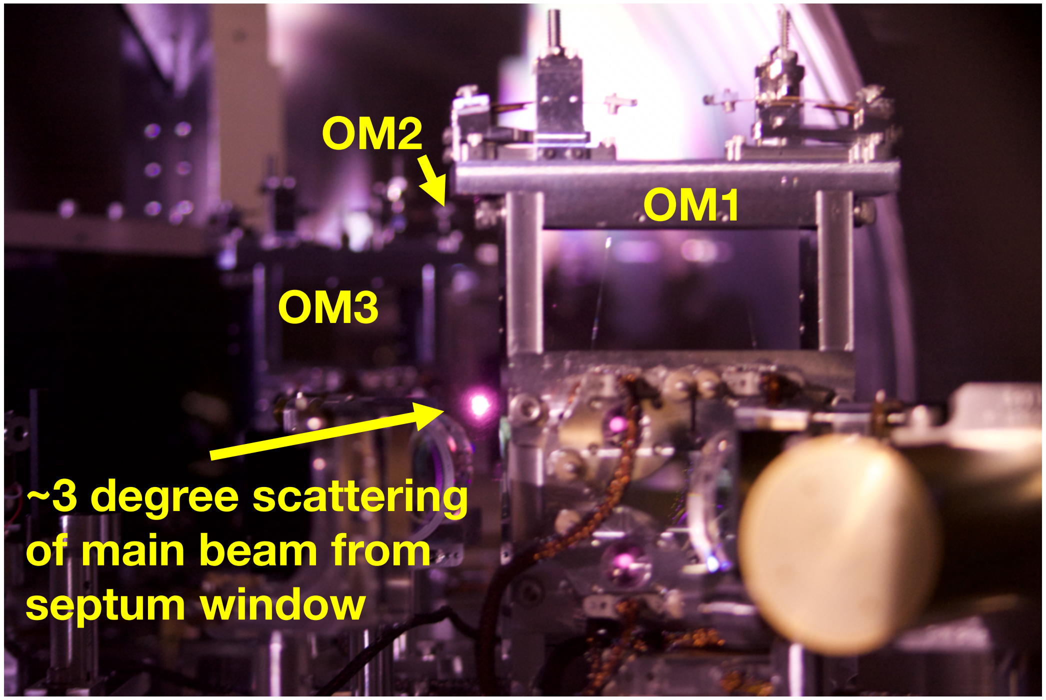
Yellow arrows indicate examined views

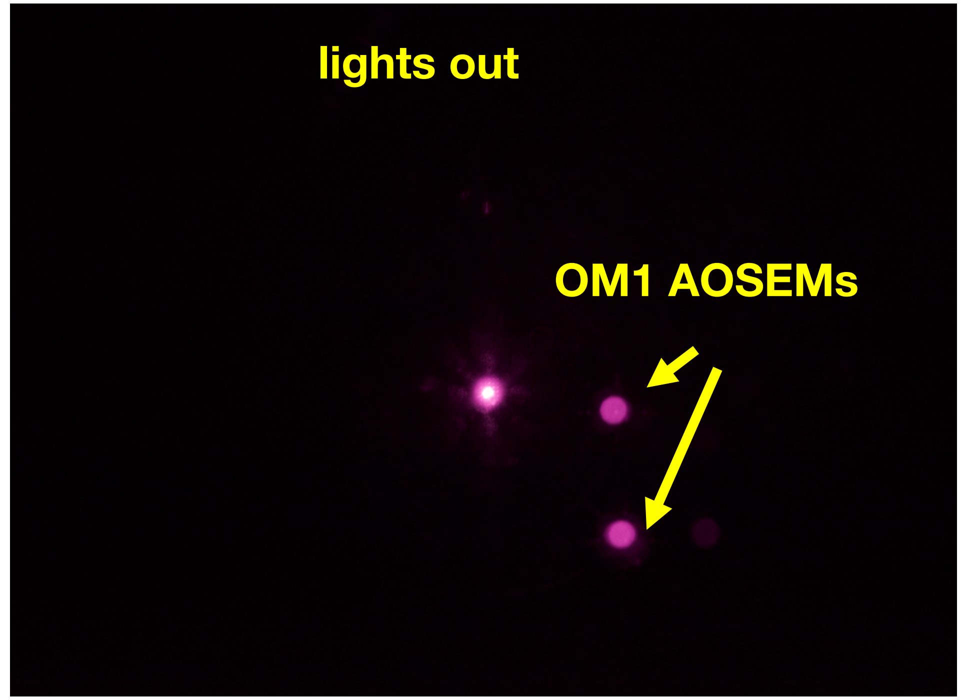




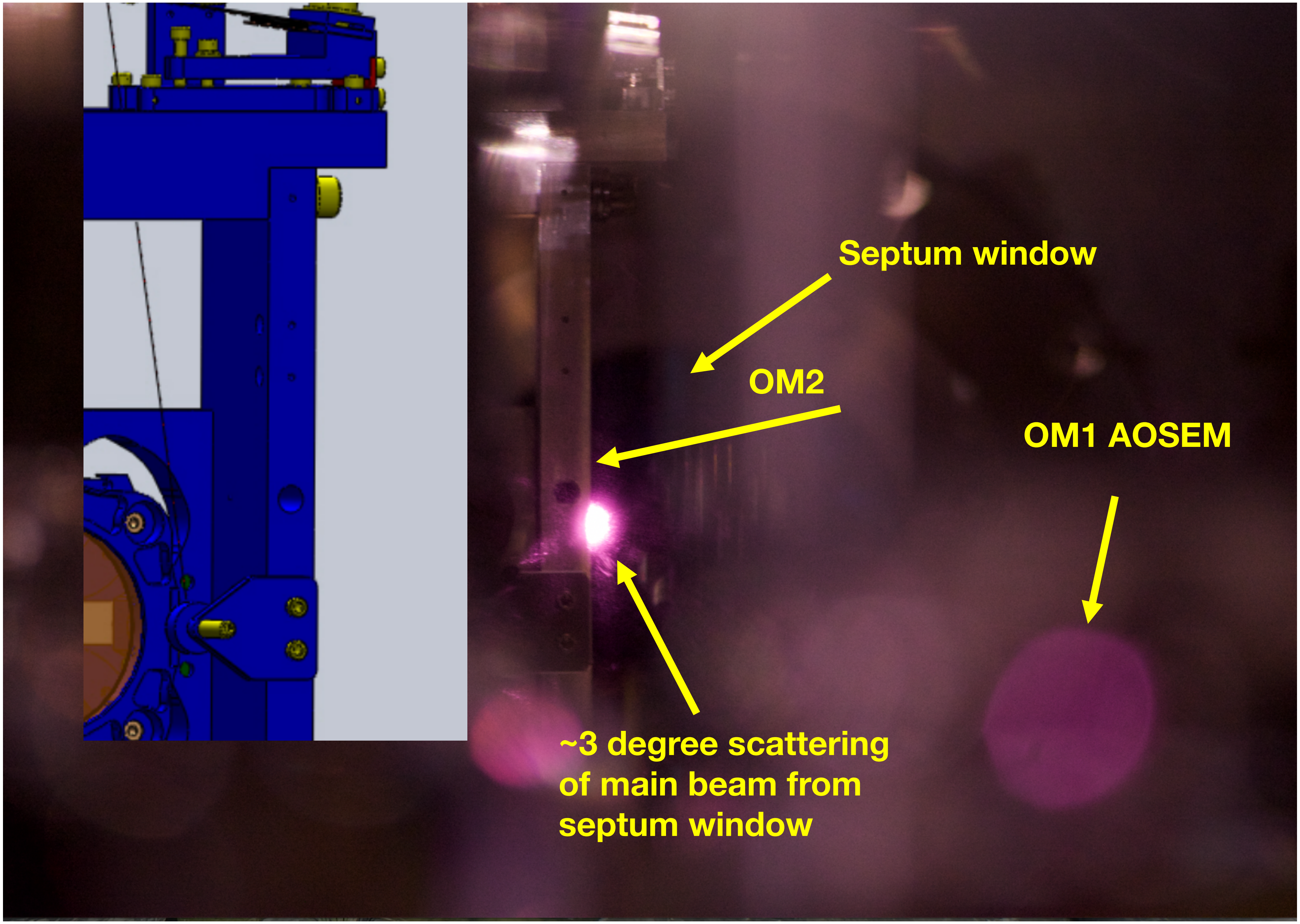


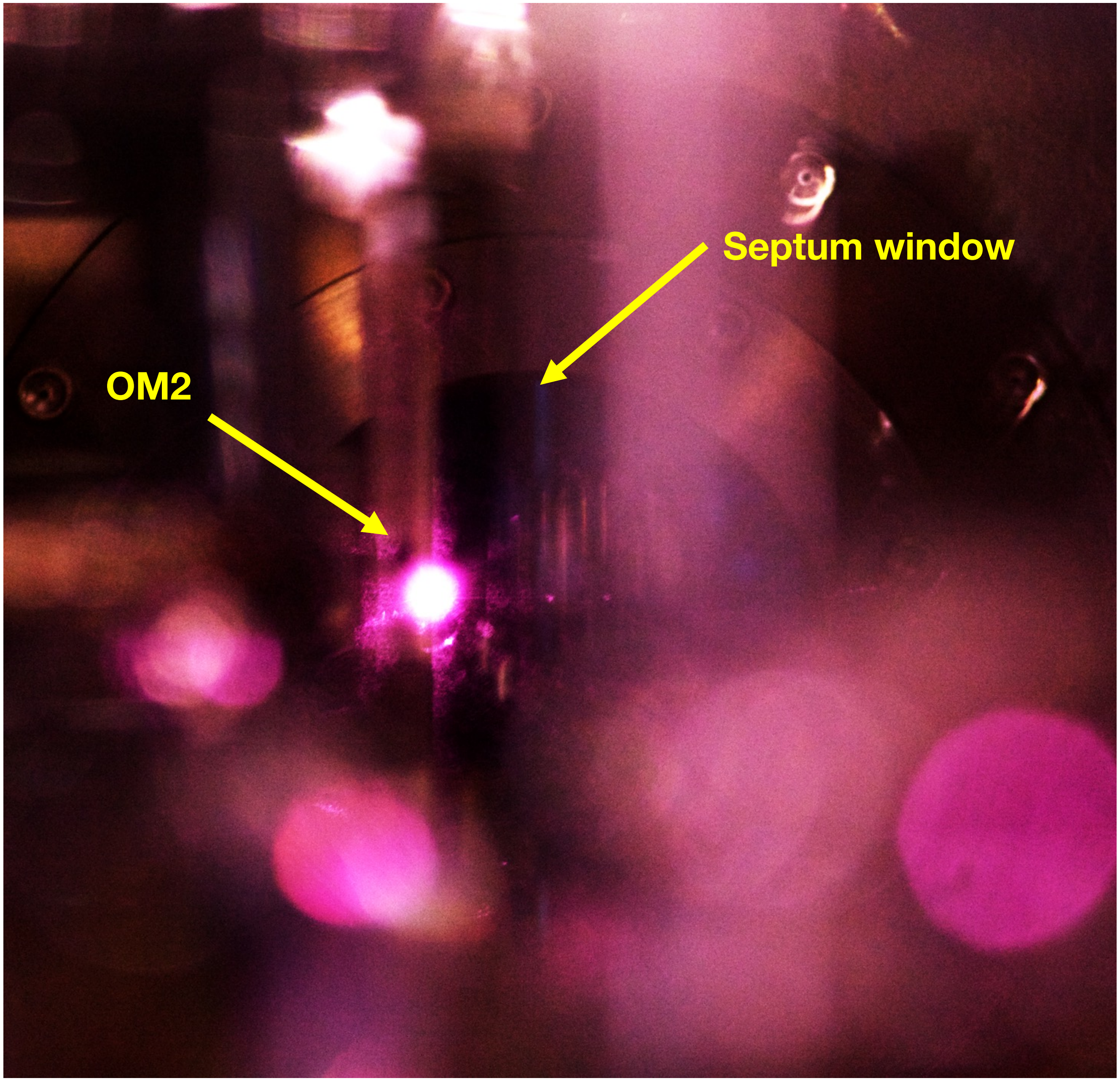

View from HAM6 endcap viewport indicated on previous page
toward septum window
40

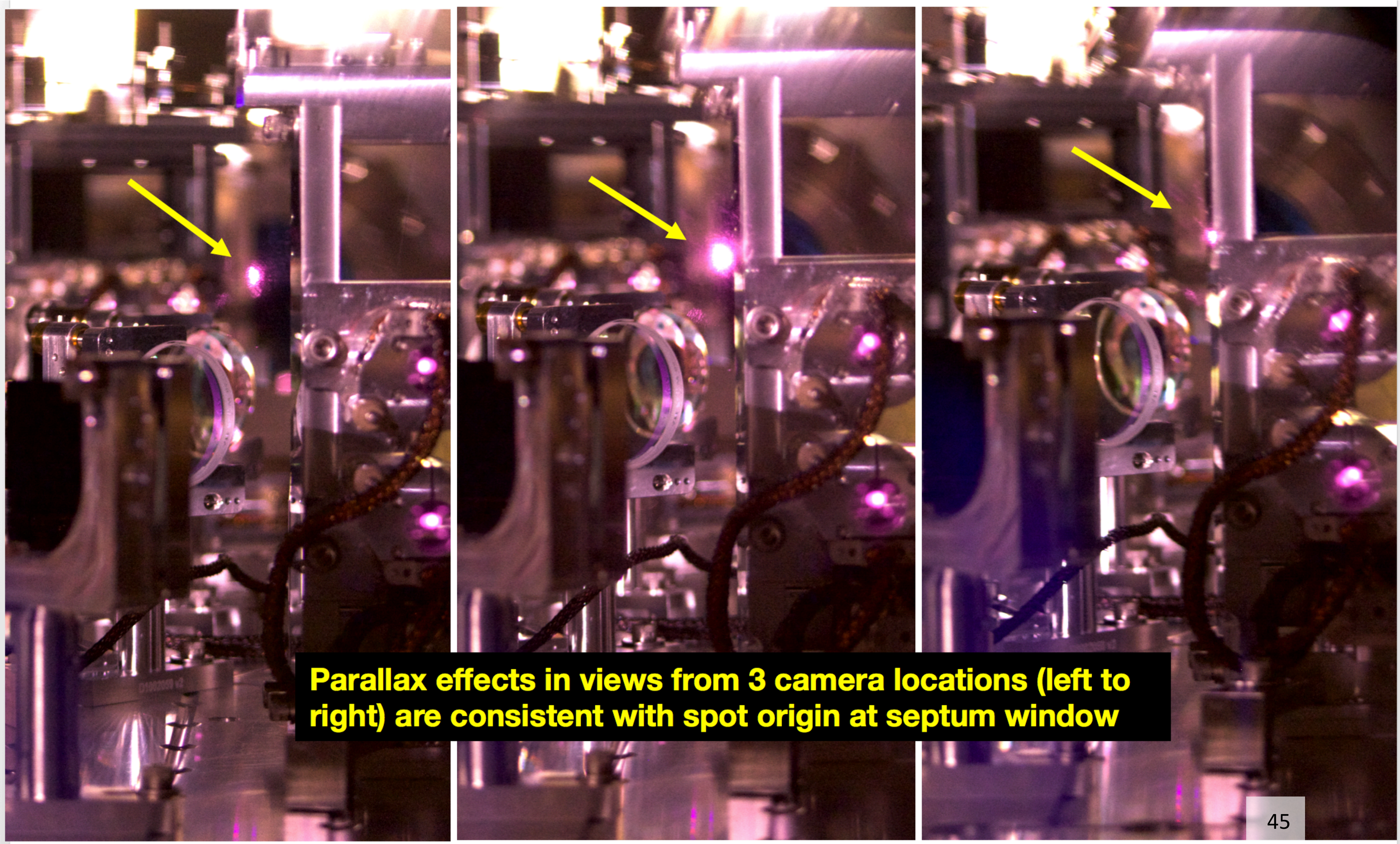

OM2
OM1
OM3
~3 degree scattering
of main beam from
septum window


lights out
OM1 AOSEMs

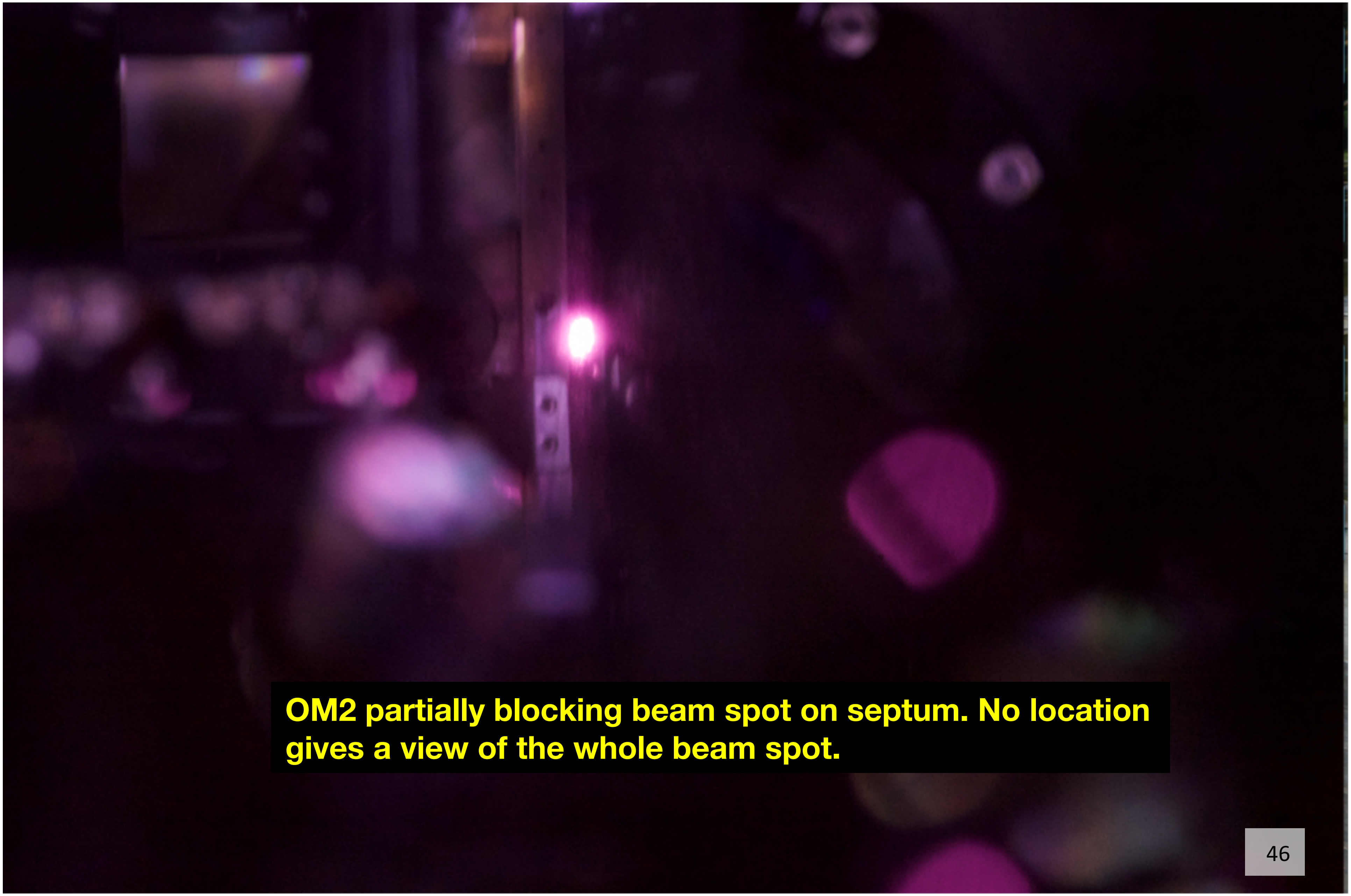

Scattering angle: ~3 degrees
septum window
(approximate)
OM2
OM1
camera view


Septum window
OM2
OM1 AOSEM
~3 degree scattering
of main beam from
septum window

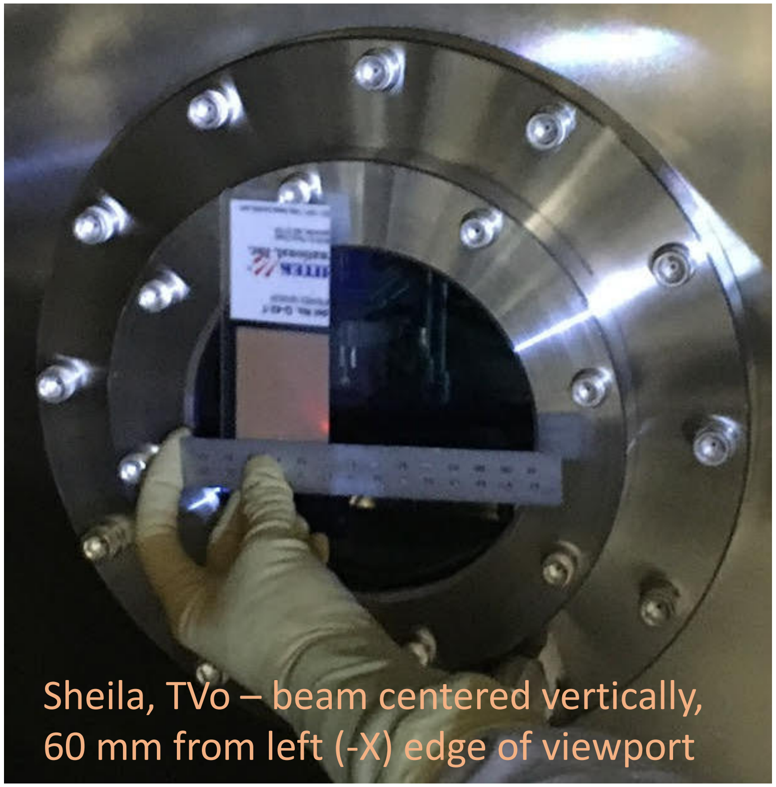

Septum window
OM2



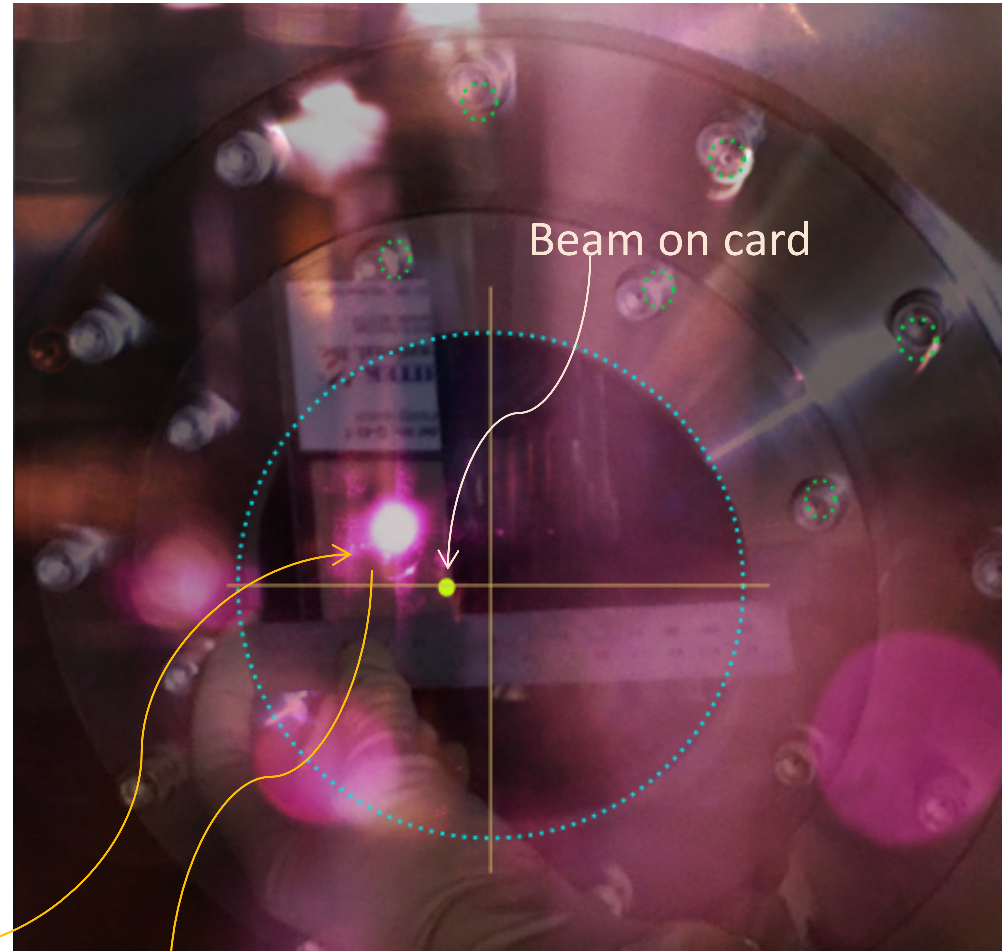
Parallax effects in views from 3 camera locations (left to right) are consistent with spot origin at septum window


OM2 partially blocking beam spot on septum. No location gives a view of the whole beam spot.

LHO septum – overlay with in air photo



-parallax of photo?– screws don't line up, card and ruler away from window
-assume we can line up viewport size from head-on photo? 5.24'' aperture



"scatter beam" ~15mm -X, ~15 mm up

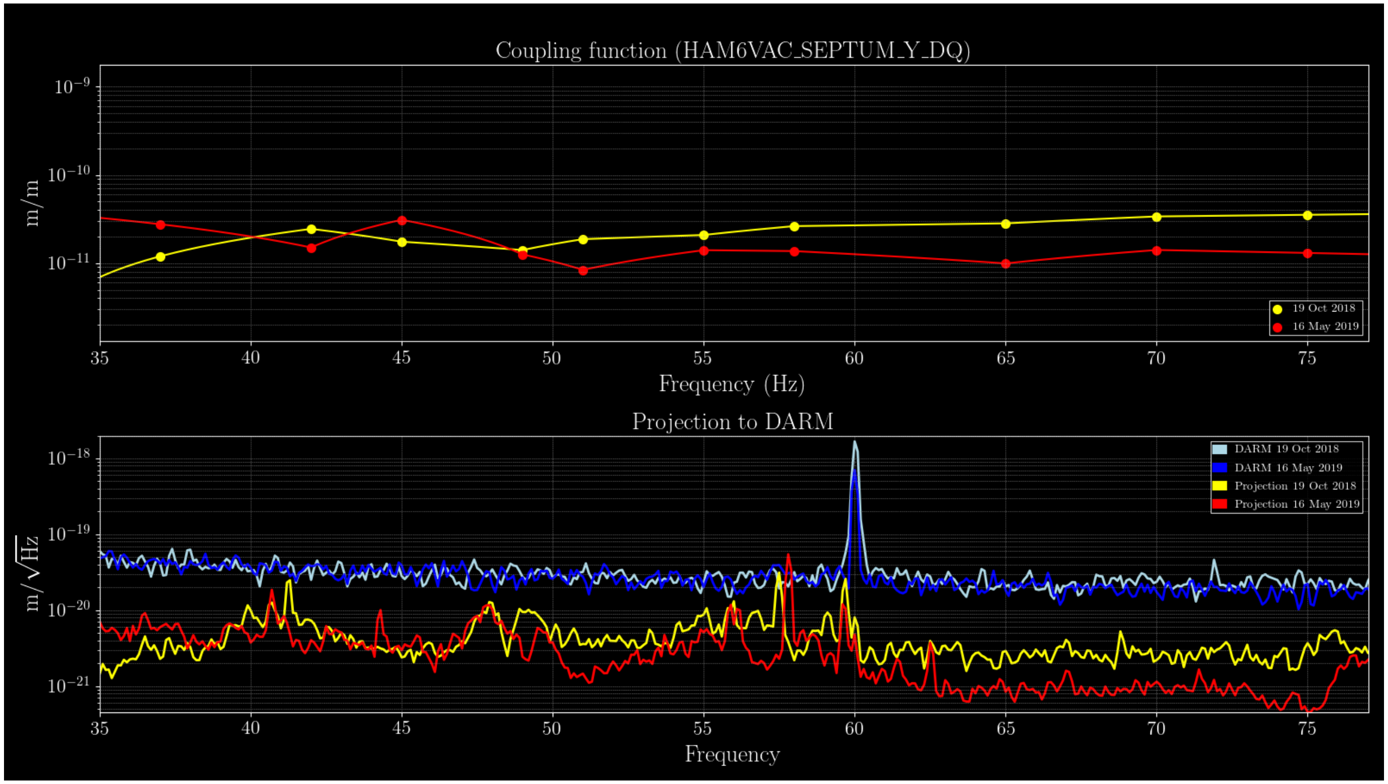
LLO HAM6 stray light photos

LLO HAM6 much ”cleaner” after OMC refl fix – still a couple of small beams
Squeezer side also ok! (just OSEM beams)
Ref: LLO alog 45378 , 45104 and 44985

LLO HAM5/6 SHAKER INJECTION CHECK

Not much change in coupling with the caveat that the reference measurement is from October

Ref: LLO alog 46010



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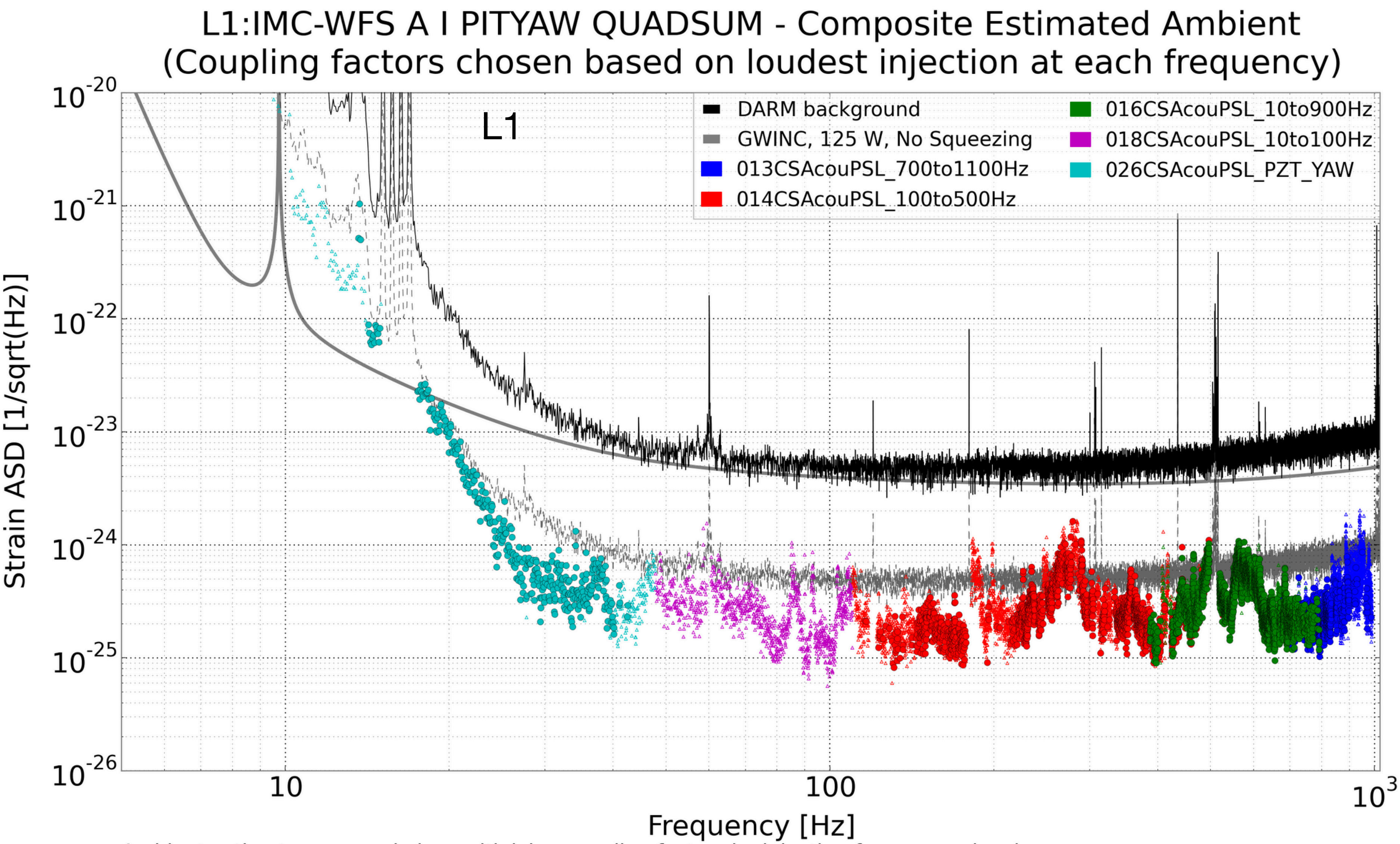
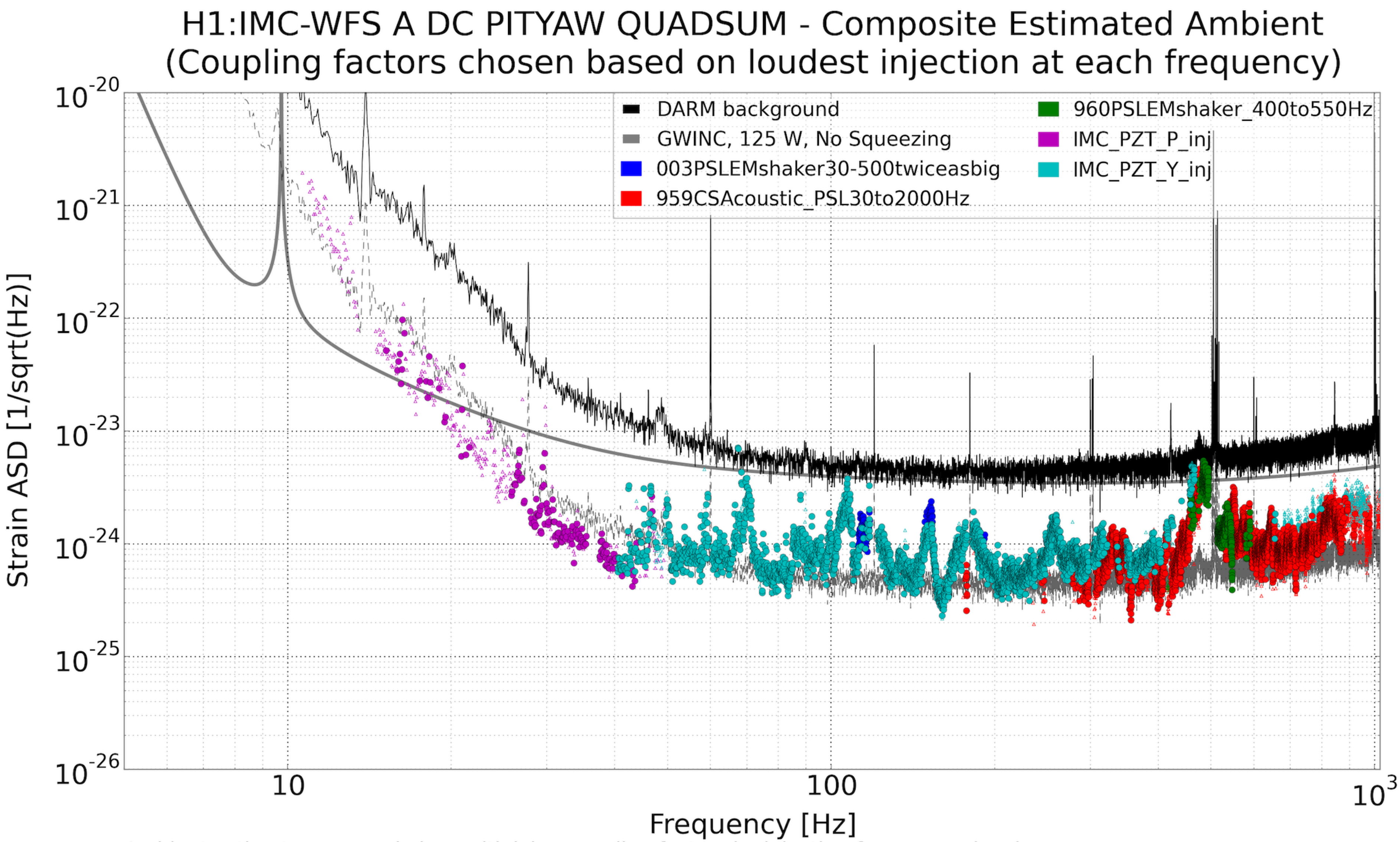
C. RF Coupling

D. Site activities



Ambient estimates are made by multiplying coupling factors by injection-free sensor levels.
CIRCLES indicate estimates from measured coupling factors, i.e. where the injection signal was seen in the sensor and in DARM.
TRIANGLES represent upper limit coupling factors, i.e. where a signal was not seen in DARM.



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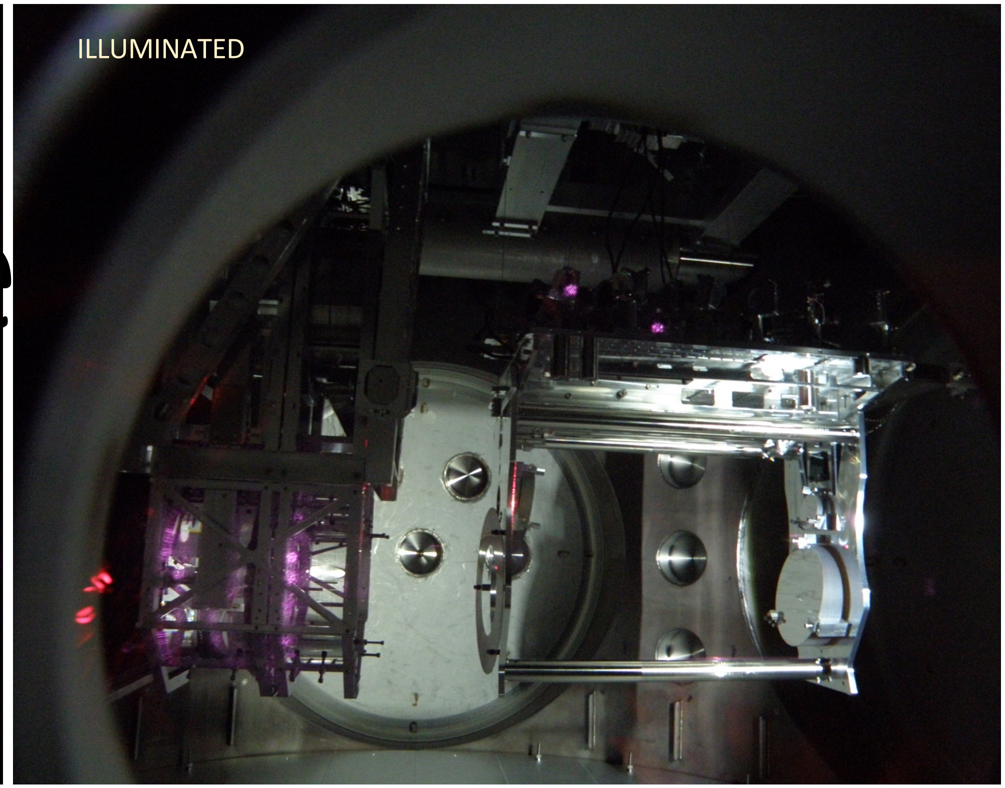
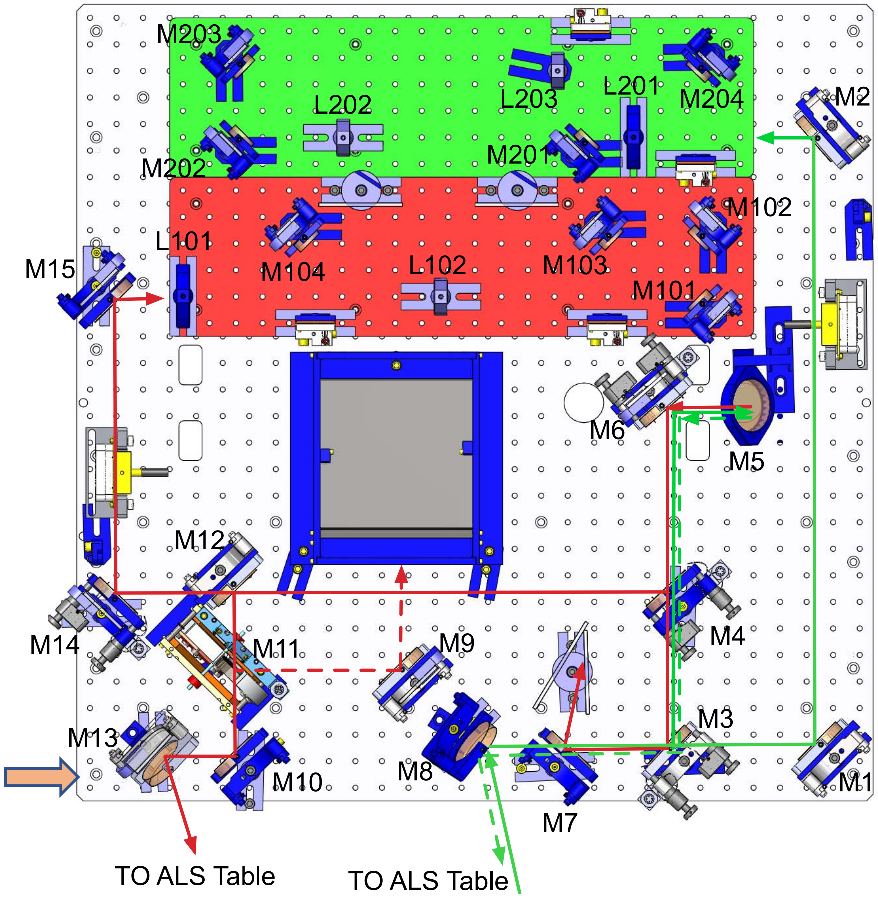
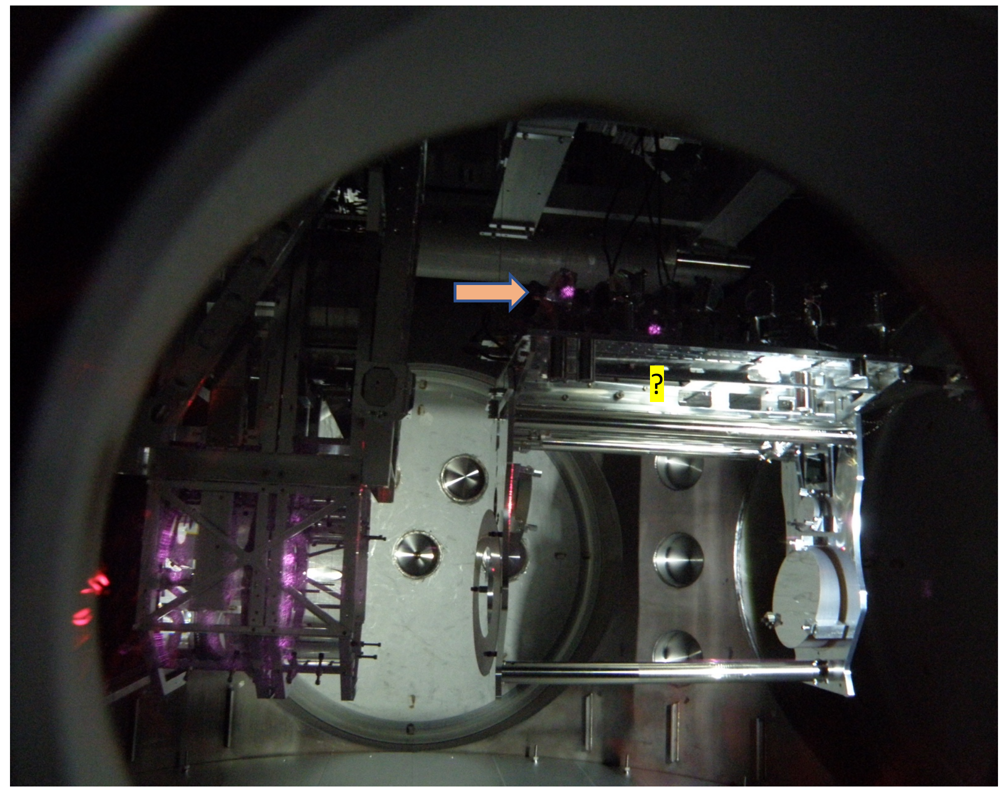
EX photos show M13 clip?



EX photos show M13 clip? Also at EY

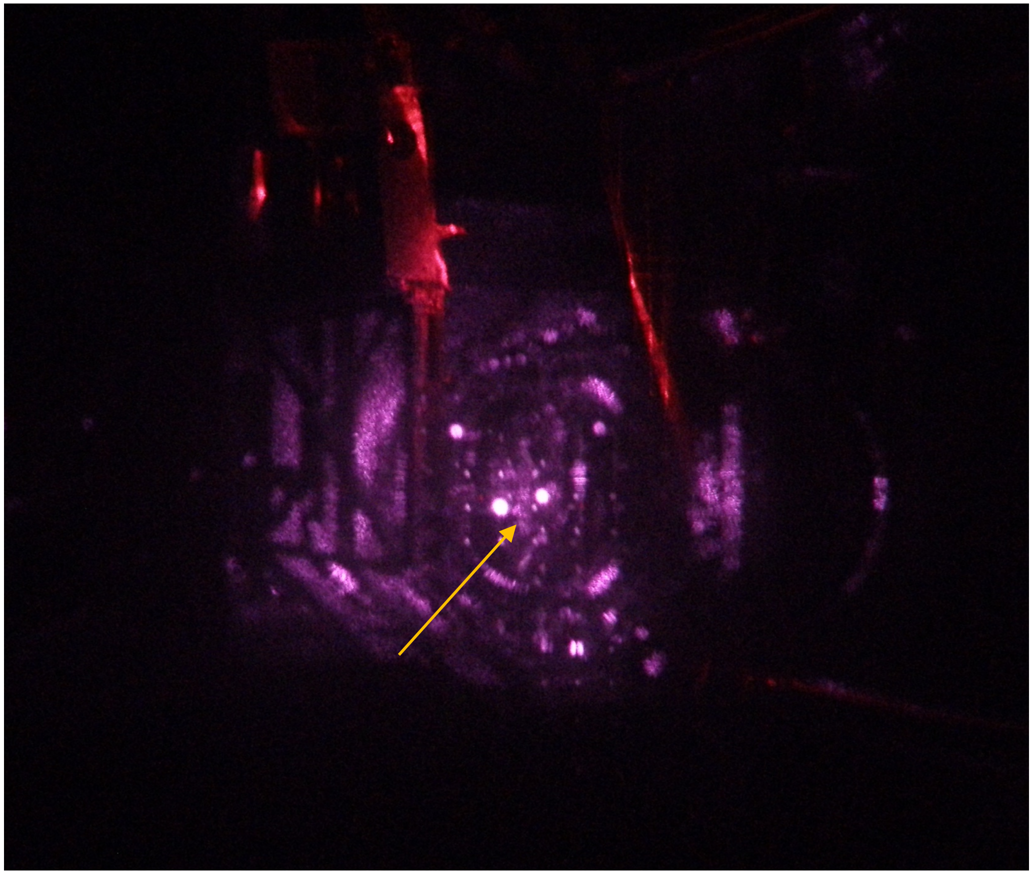




LLO End Station Photos in Full Lock

- Stray beams on walls at EY
- Stray beams on ACB
- Some clipping on transmon optics
- Some beams on test masses?
- General brightness all over the cage, reaction mass
- Floors look “clean”
- *Unclear what matters*

Ref LLO alog: 45469 (needs update)



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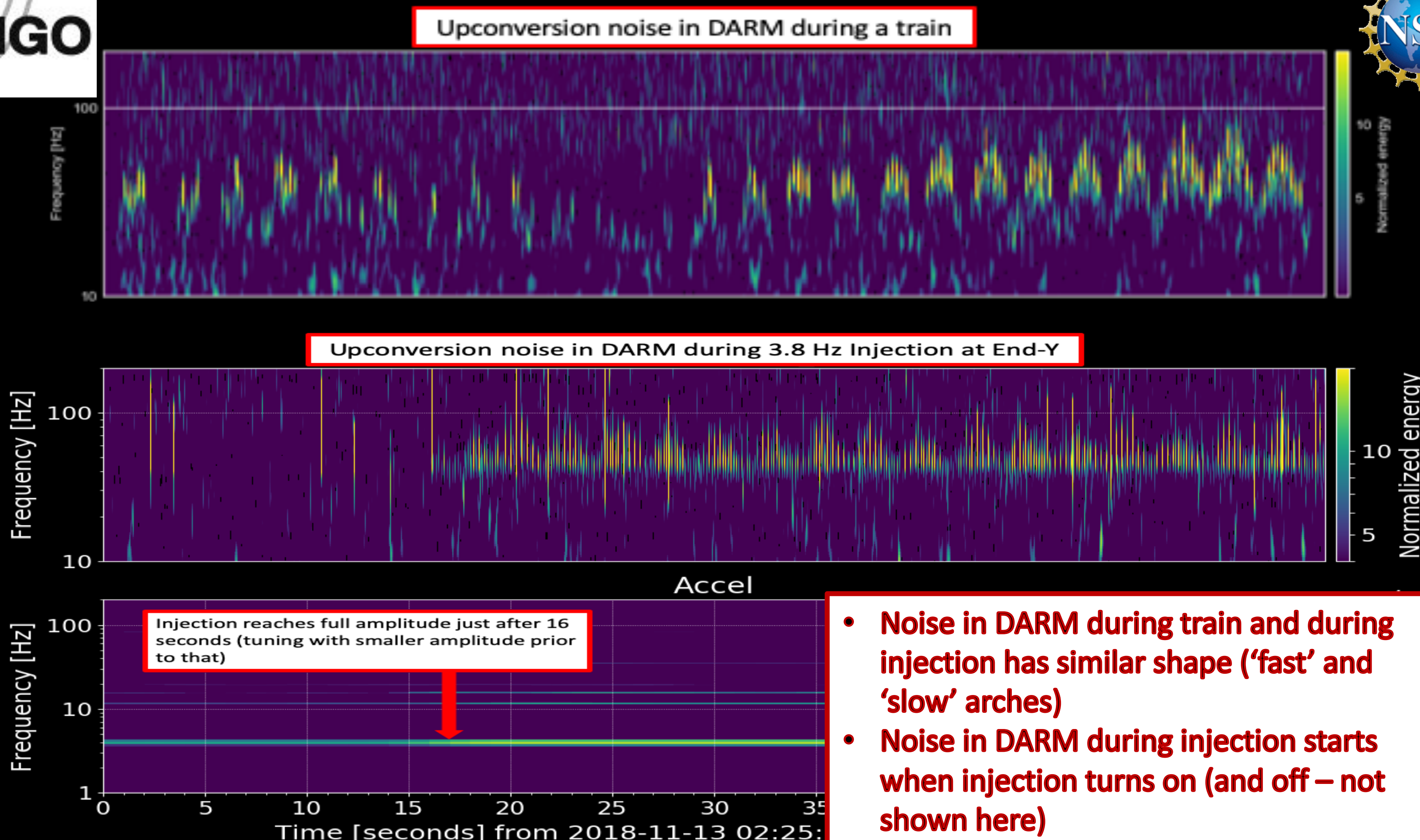

- Noise in DARM during train and during injection has similar shape ('fast' and 'slow' arches)
- Noise in DARM during injection starts when injection turns on (and off – not shown here)

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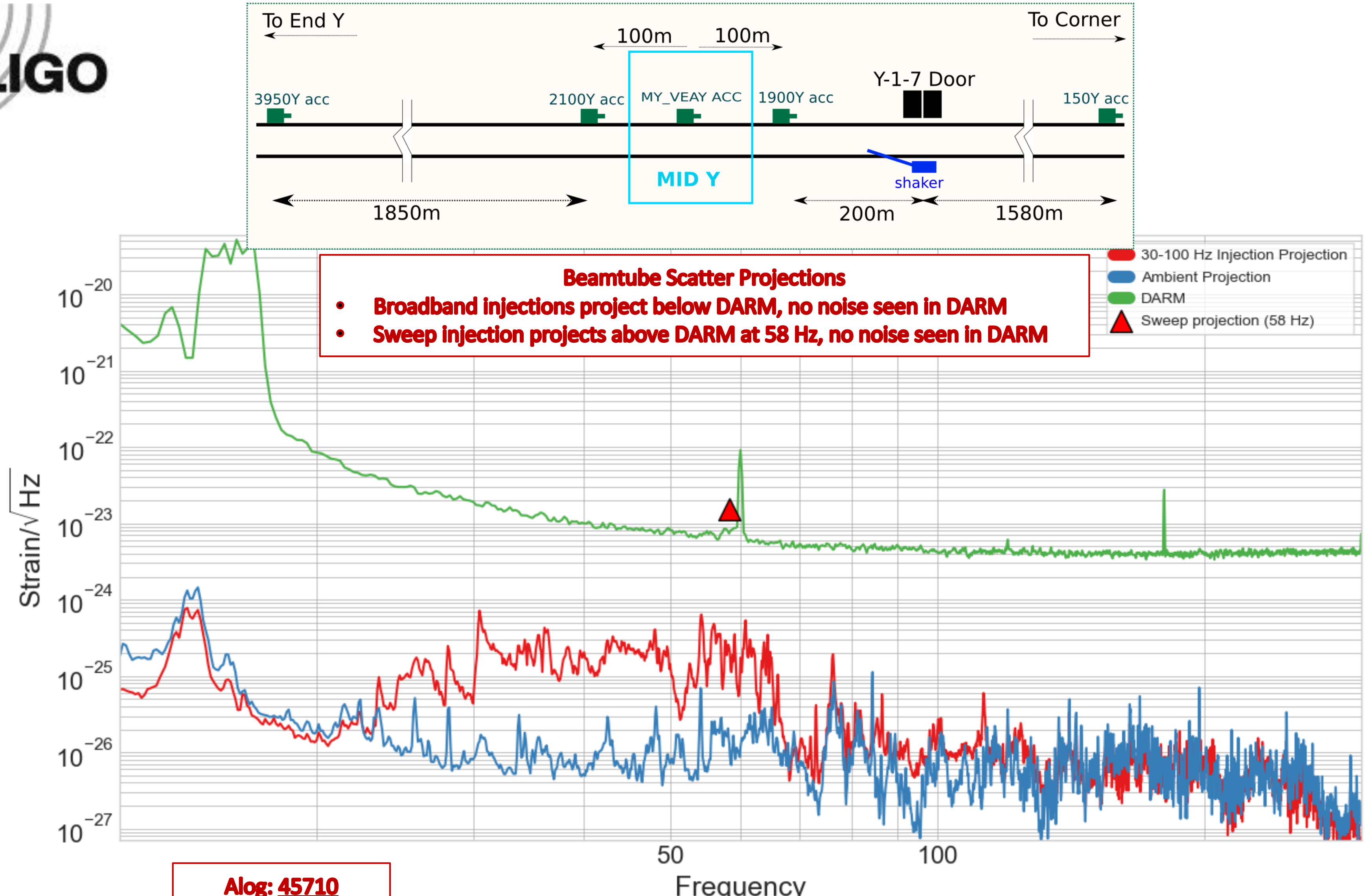
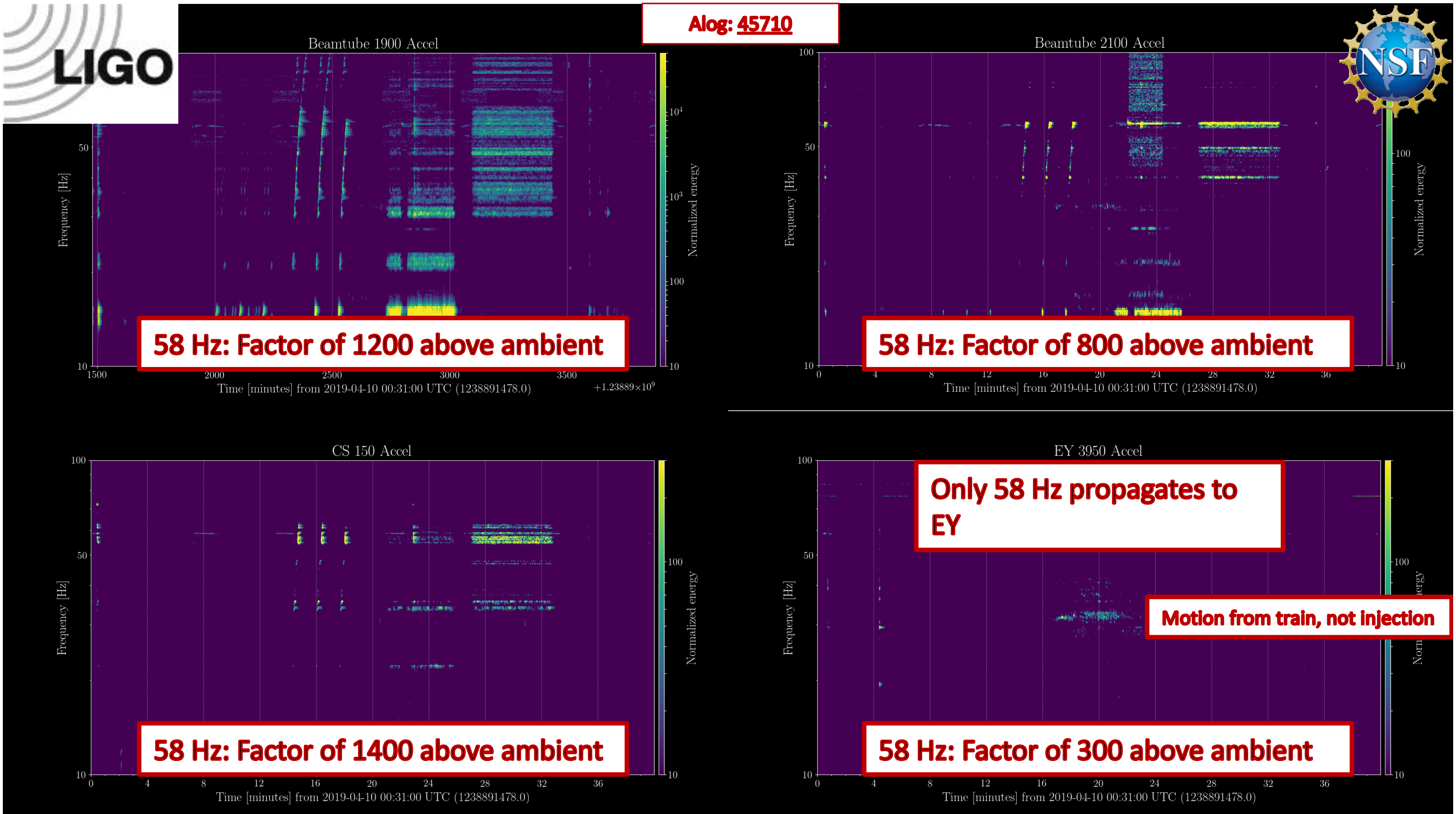


Beamtube Scatter Projections

- **Broadband injections project below DARM, no noise seen in DARM**
- **Sweep injection projects above DARM at 58 Hz, no noise seen in DARM**

Alog: 45710


Alog: 45710
Beamtube 1900 Accel
58 Hz: Factor of 1200 above ambient
Beamtube 2100 Accel
58 Hz: Factor of 800 above ambient
CS 150 Accel
58 Hz: Factor of 1400 above ambient
EY 3950 Accel
Only 58 Hz propagates to EY
Motion from train, not injection
58 Hz: Factor of 300 above ambient
Frequency [Hz]
Normalized energy
Time [minutes] from 2019-04-10 00:31:00 UTC (1238891478.0)

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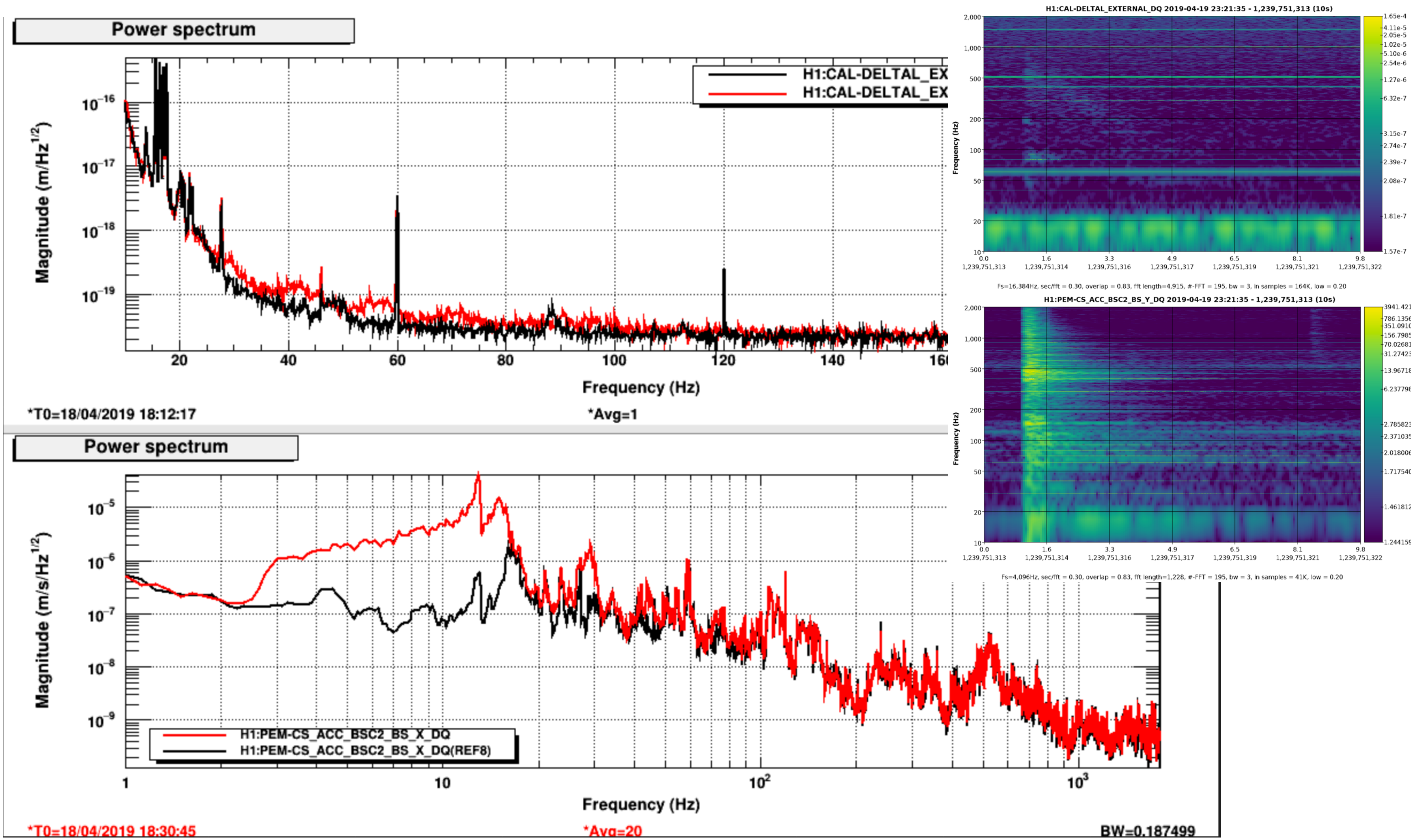
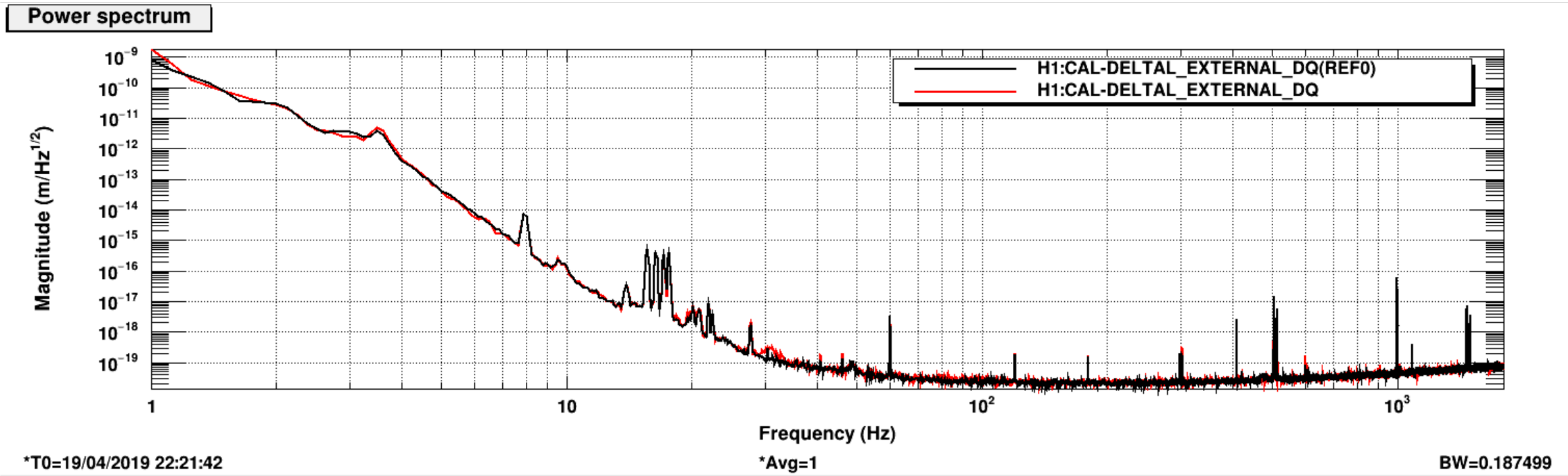
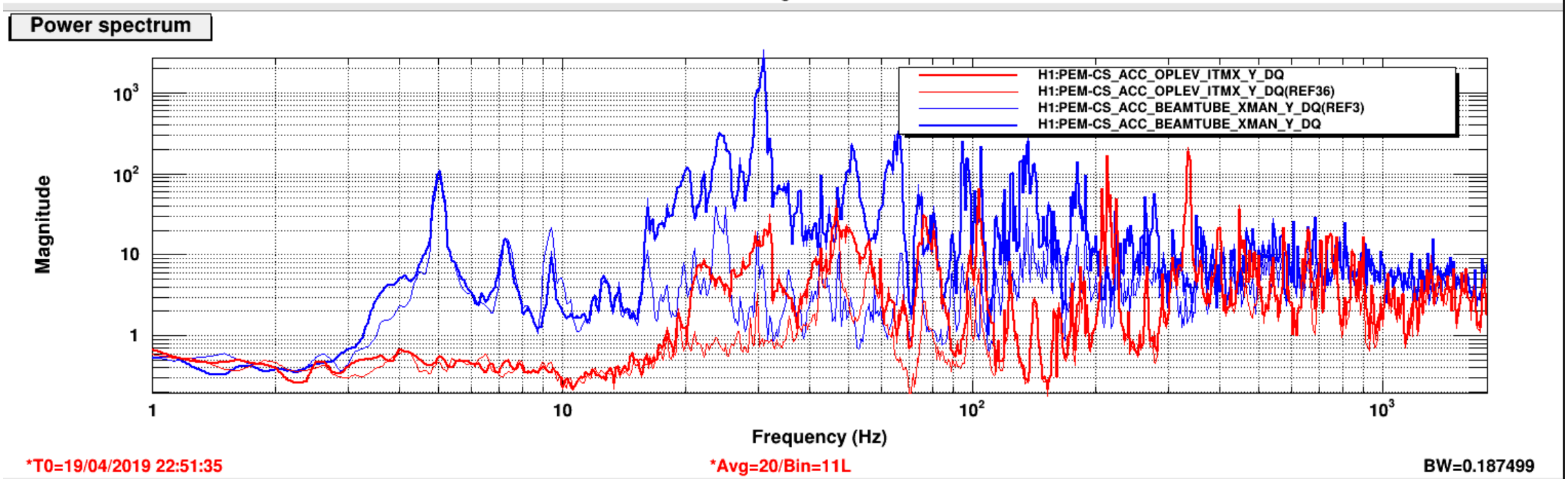
Shaking of BSC2 wall

Impulse



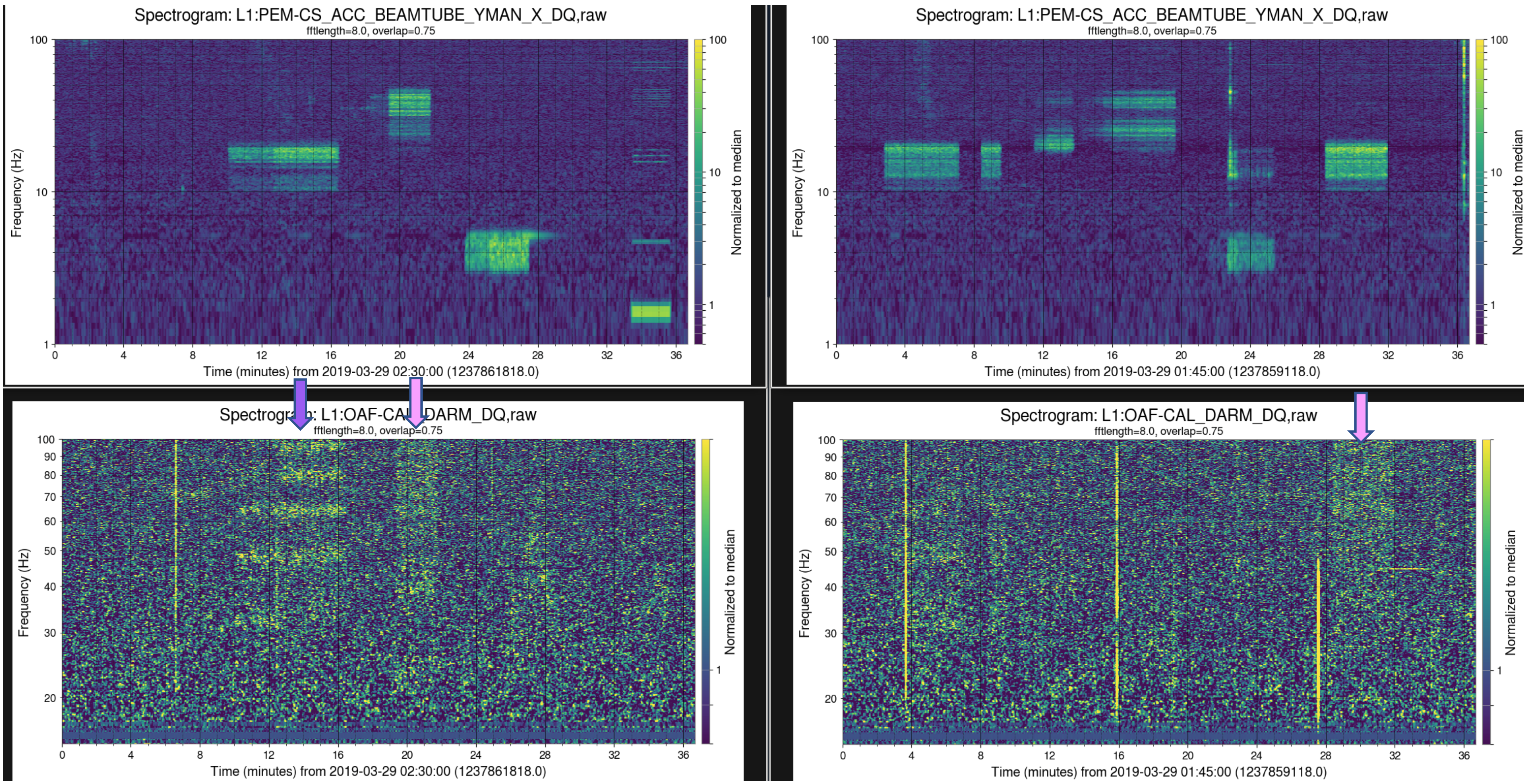
Shaking of manifold reduction flange near ITMX optical lever





LLO LVEA Y TUBE INJECTIONS (still to analyze)

Y Red. Flange INJ **BSC1 INJ**



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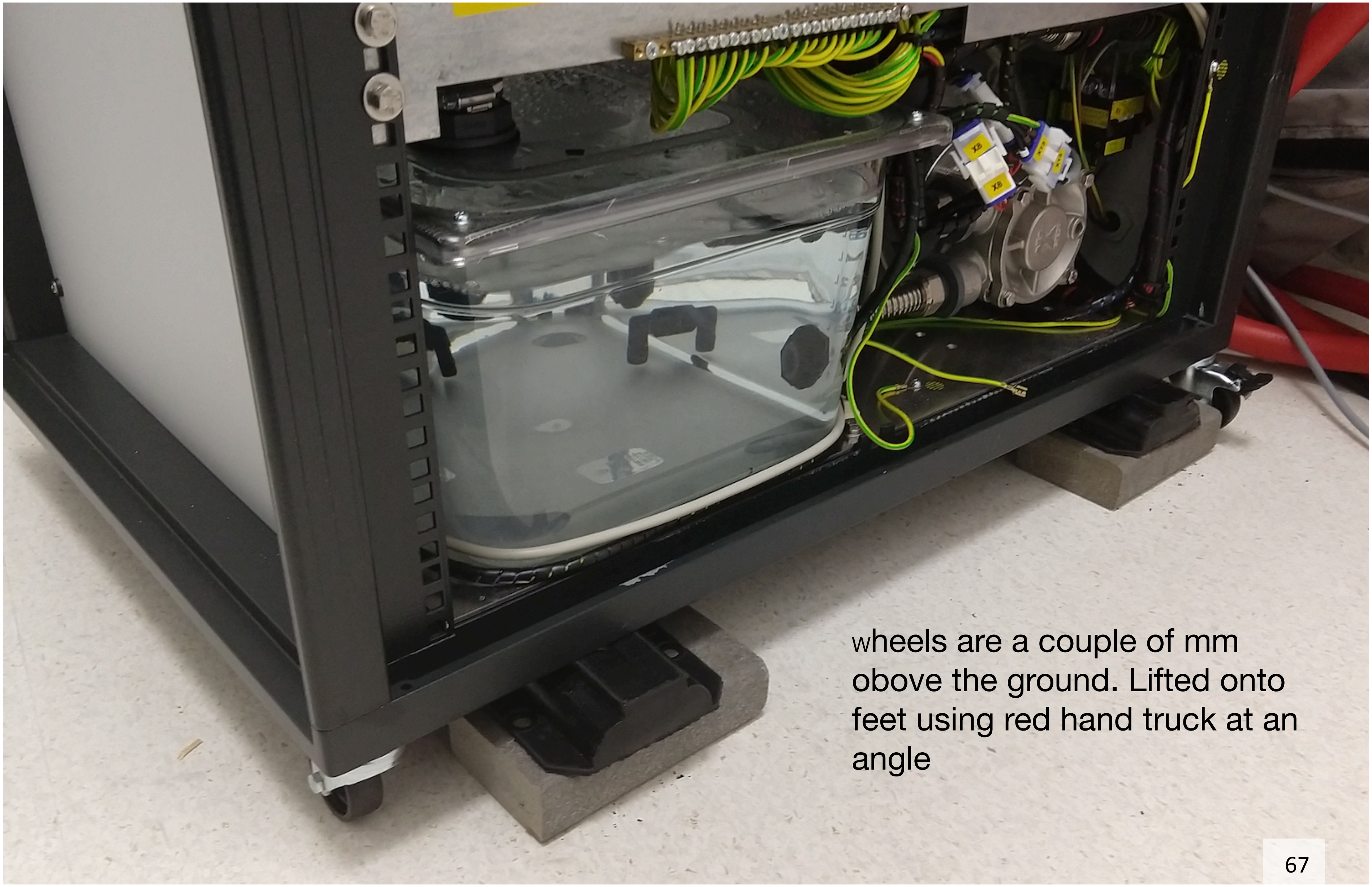

wheels are a couple of mm obove the ground. Lifted onto feet using red hand truck at an angle

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No coupling (to x10 or better)

Site	Location	Injection Type	Relevant to
LHO, LLO	mids	Acoustic/shaker 10-100 Hz	Beamtube scatter
LHO, LLO	IOT2L (IMC table)	Acoustic/shaker 10-100 Hz	Local coupling
LHO, LLO	IMC tube (HAM2-3)	Shaker 5-100 Hz	Local coupling
LHO	HEPI EX, EY, BS, IX, IY	HEPI Inj 1-100 Hz, beam dof	ACB, BS baffles, scatter
LLO	ISI all BSC and HAM	ISI Inj 1-5 Hz, beam and r dofs	Daytime scatter
LLO	Arm beamtube	Shaker ~58 Hz	Beamtube scatter
LHO, LLO	SRC tube (HAM4-5)	Shaker 5-100 Hz	Local coupling

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L1 PEM (Detchar, PEM) Link

philippe.nguyen@LIGO.ORG - posted 15:21, Friday 17 May 2019 (46025)

Coupling estimates from PEM injections correctly predict LLO DARM glitch near S190510g from thunder-driven vibration at EY

Philippe N, Robert S,

We looked at a long duration Omega scan covering the 20 seconds before the event time of S190510g (where the most scattering noise was observed) and found that many L1 PEM accelerometers and microphones saw excess noise around the same time as the noise in DARM. I ran my own offline version of the DQR PEM check on this Omega scan to estimate coupling into DARM. The coupling functions predict the highest contribution at EY, with several EY accelerometers roughly predicting the 11.5 SNR in DARM reported by the omegascan.

Link to the omegascan report: https://ldas-jobs.ligo-la.caltech.edu/~philippe.nguyen/omega/1241492387/

Link to the pemcheck results: https://ldas-jobs.ligo-la.caltech.edu/~philippe.nguyen/omega/1241492387/pemcheck-results.html

The DQR Omega scan is configured to a search window duration of only +/- 0.5 s around event time, regardless of the template duration, so the DQR PEM check, which relies on the output of that scan, could not provide the above predictions. If those Omega scans were expanded (by having a fixed, longer-duration scan, by adapting the searchWindowDuration config option to cover the template duration, or by simply re-running them by hand), the PEM check would be able to make more useful estimates.

The vibration source that produced the signal in DARM is likely distant thunder: the signals show up at all stations with reasonable delays for sound propagation, sound like thunder in mp3s, have the right frequency content and duration, and one of the loud events was consistent with the time put in by an operator for a loud thunder clap.

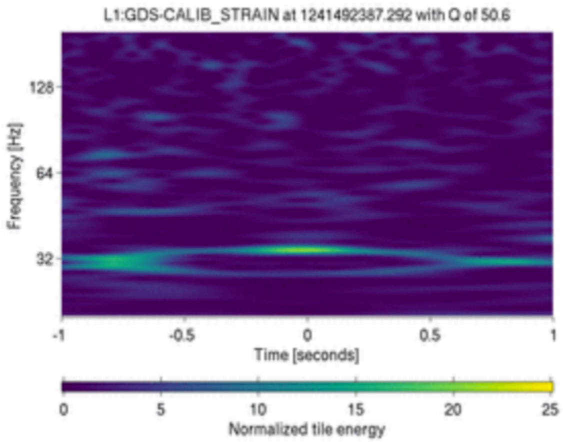
The second page of the attached pdf shows that events in DARM are coincident with the EY mic, but not the mics at the other stations. Because thunder is a global injection with time delays, it is a good test of dominant vibration coupling sites. Our shaker injections suggested that EY is the dominant coupling site in this band. The PEM injection results are supported by the correct prediction of the DARM event by the EY accelerometer and the absence of DARM events for other stations.

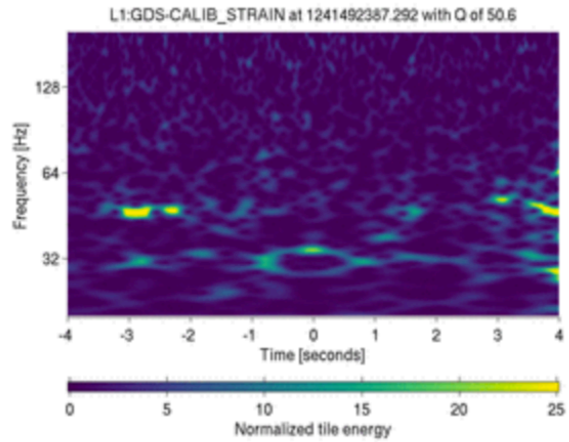
Below are links to Omega scans covering the other two thunder events and their PEM checks, which show that the EY coupling predicts the DARM amplitudes for those events as well:

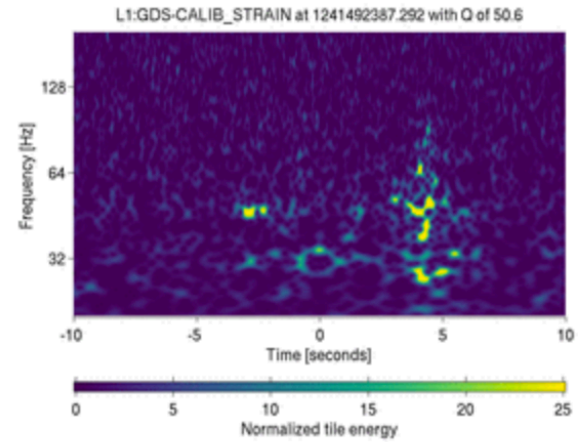
https://ldas-jobs.ligo-la.caltech.edu/~philippe.nguyen/omega/1241493373/

☑ L1:GDS-CALIB_STRAIN

most significant tile: t = 1241492384.438 s, f = 46.6 Hz, Q = 50.6, Z = 6.6×10^{1}, X = 7.5×10^{-23} $Hz^{-1/2}$, SNR = 11.5
time series: raw, high passed, whitened | spectrogram: raw, whitened, autoscaled | eventgram: raw, whitened, autoscaled

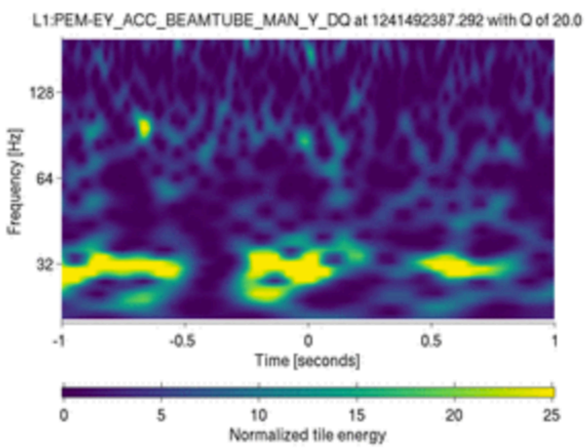


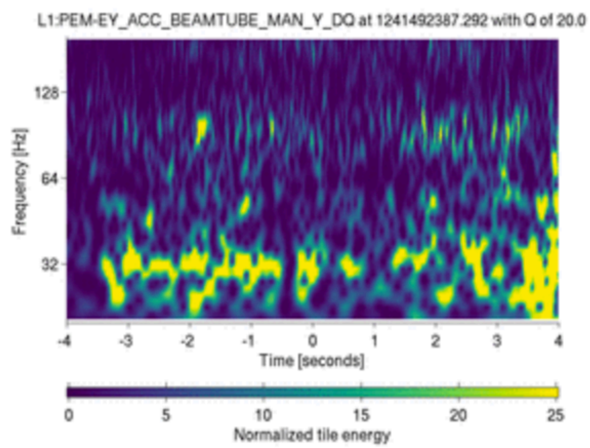


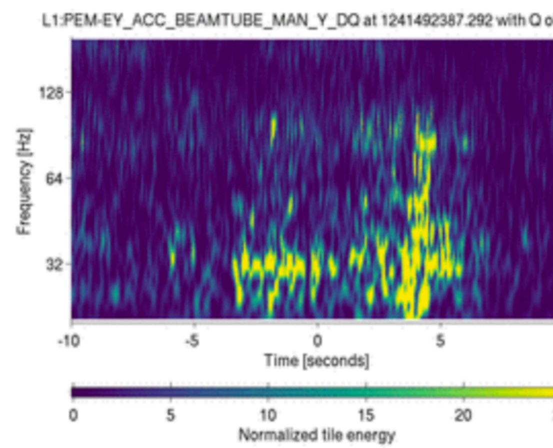


☑ L1:PEM-EY_ACC_BEAMTUBE_MAN_Y_DQ

most significant tile: t = 1241492390.906 s, f = 30.9 Hz, Q = 20.0, Z = 3.2×10^{2}, X = 6.2×10^{1} $Hz^{-1/2}$, SNR = 25.4
time series: raw, high passed, whitened | spectrogram: raw, whitened, autoscaled | eventgram: raw, whitened, autoscaled

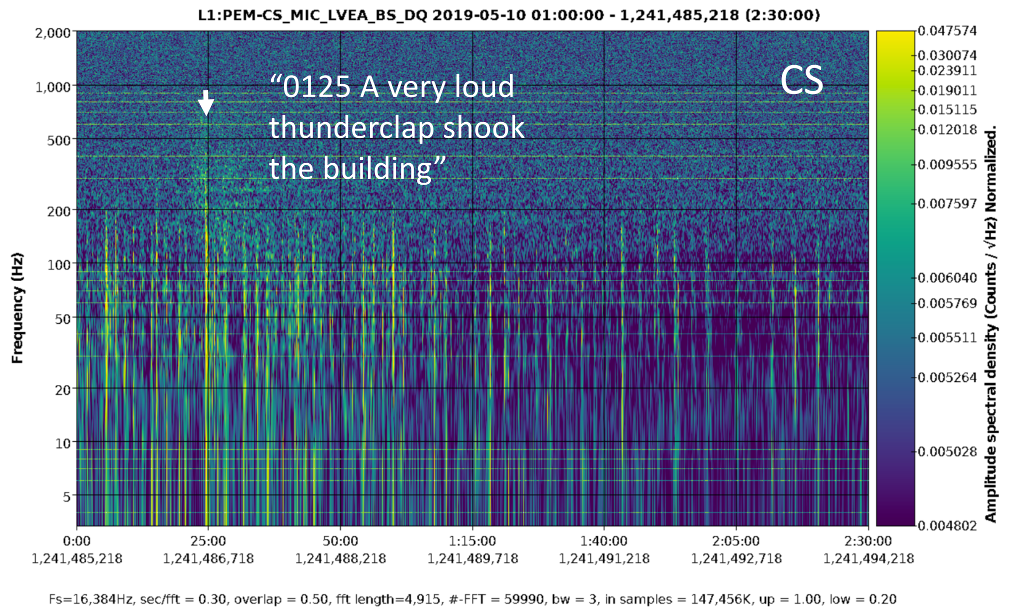


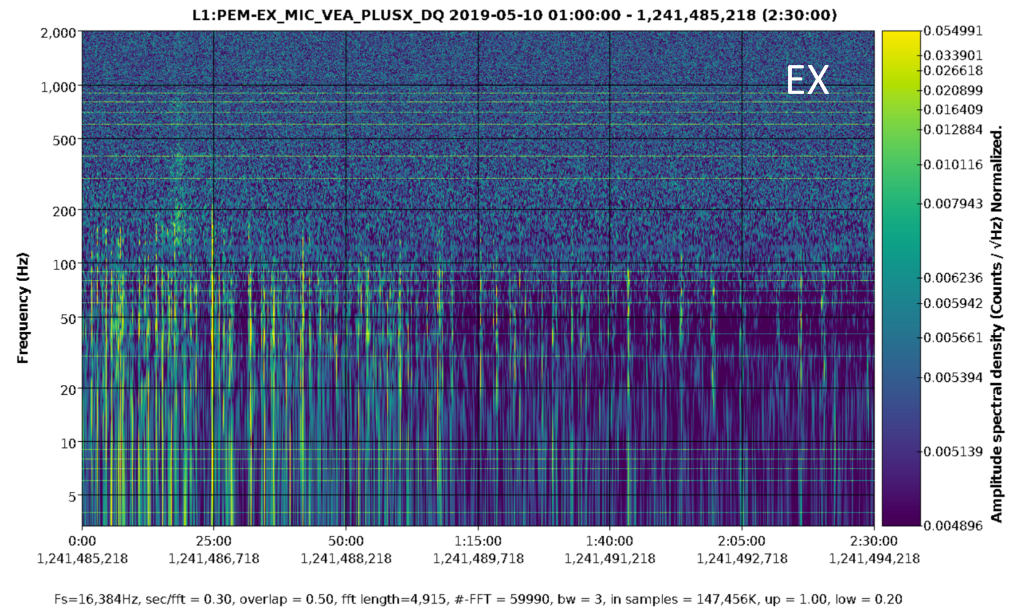


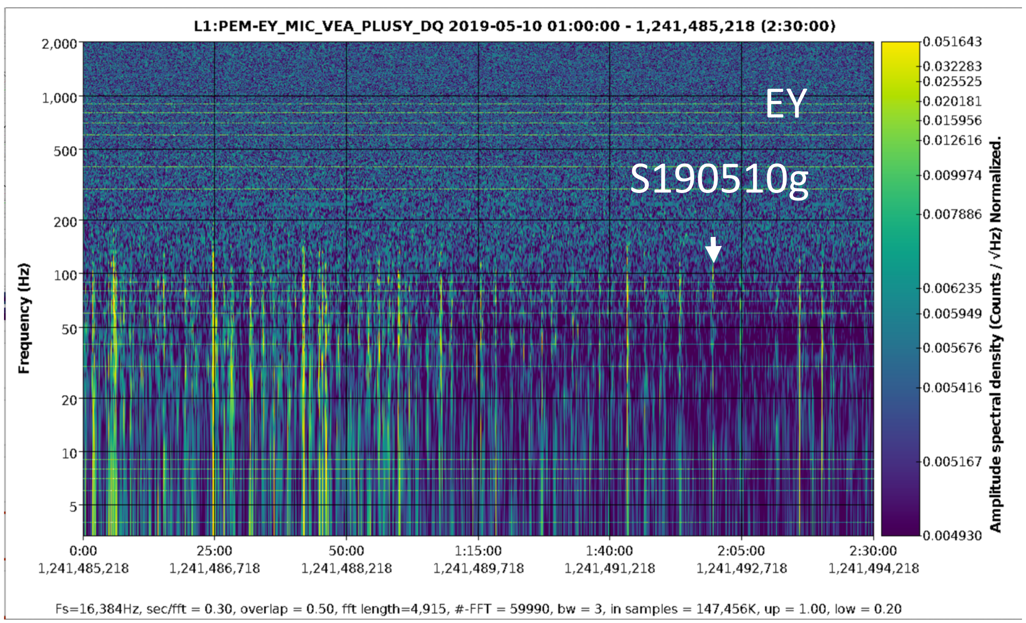


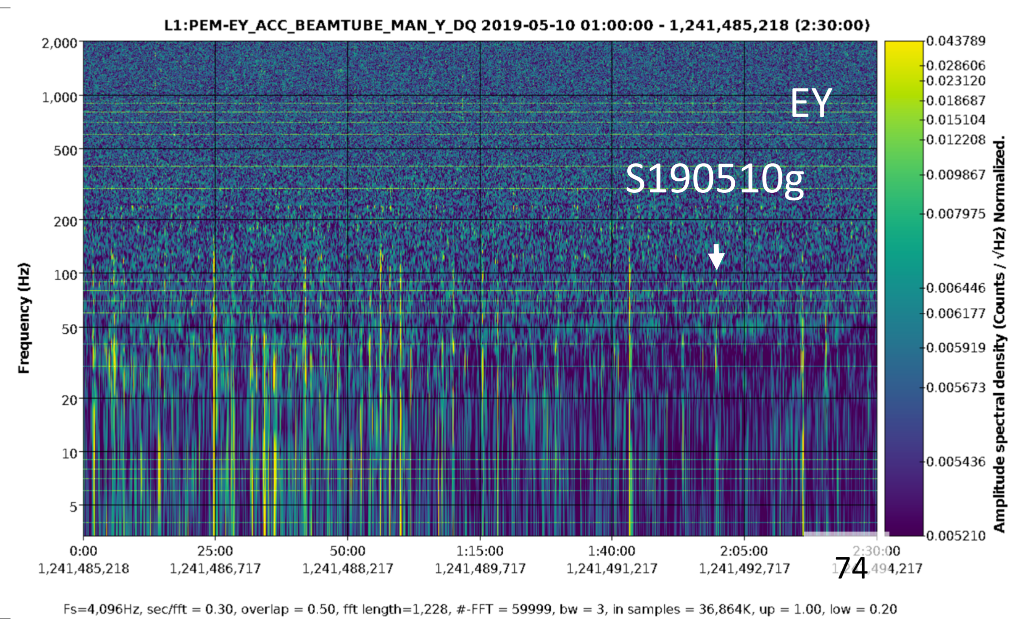
a

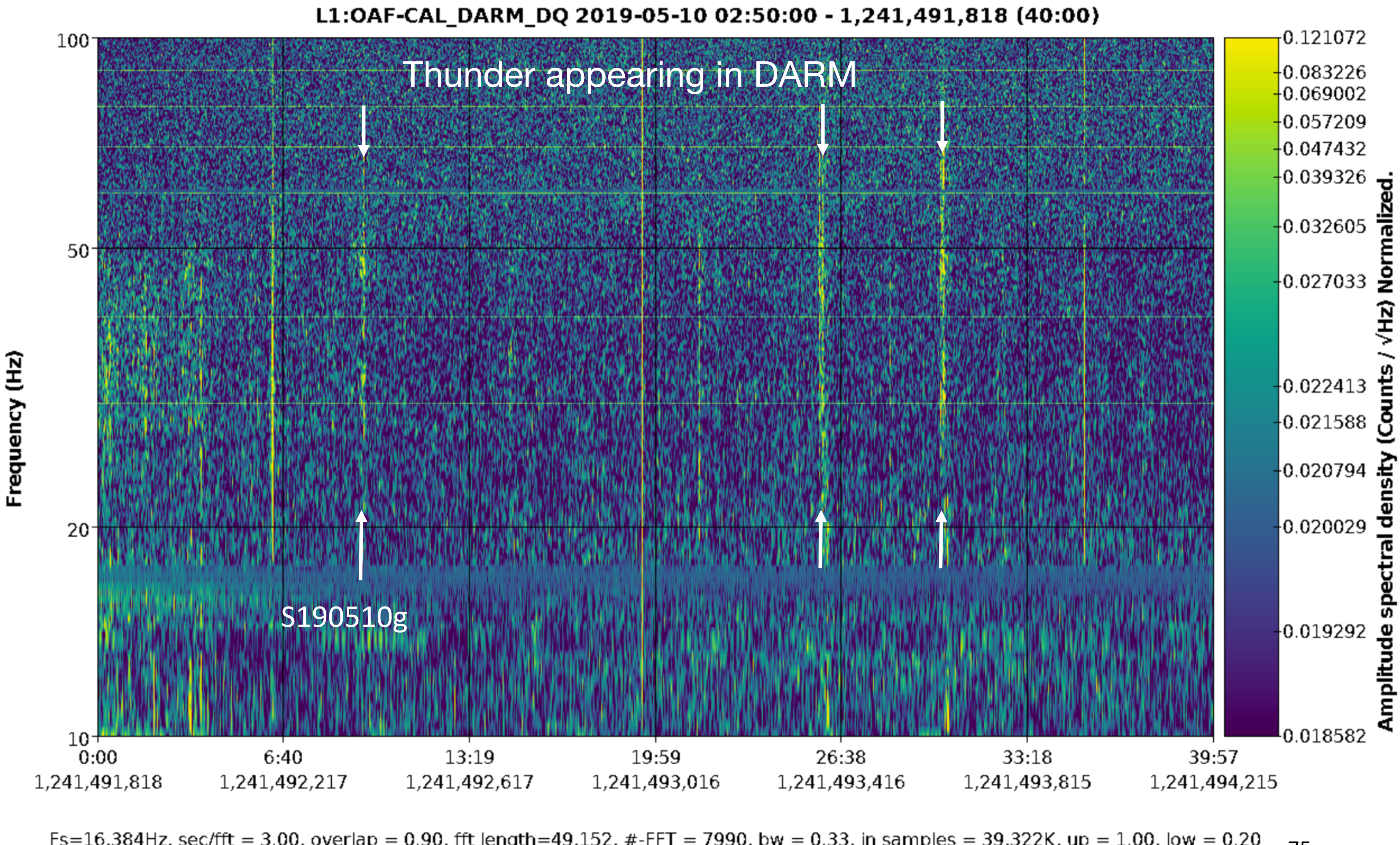
Channel	Peak frequency	Peak amplitude	Coupling function at peak freq	Coupling function flag	Estimated DARM amplitude	DARM background	Estimated amplitude / bkgd
L1:PEM-EY_ACC_BEAMTUBE_MAN_Y_DQ	30.9	6.2e+01	1.7e-20	Upper Limit	1.0e-18	7.6e-20	13.85
L1:PEM-EY_ACC_BSC5_ETMY_X_DQ	47.3	3.7e+01	7.6e-21	Measured	2.8e-19	3.4e-20	8.31
L1:PEM-EY_ACC_BSC5_ETMY_Y_DQ	47.3	9.6e+01	2.9e-21	Measured	2.7e-19	3.4e-20	8.17
L1:PEM-EY_ACC_VEA_FLOOR_Z_DQ	32.7	1.3e+01	3.0e-20	Upper Limit	3.9e-19	5.9e-20	6.70
L1:PEM-EY_ACC_BEAMTUBE_MAN_Z_DQ	47.3	3.9e+01	5.0e-21	Measured	2.0e-19	3.4e-20	5.89
L1:PEM-EX_ACC_BSC4_ETMX_X_DQ	28.1	2.2e+01	1.4e-20	Upper Limit	3.1e-19	7.2e-20	4.33
L1:PEM-EY_ACC_OPLEV_ETMY_X_DQ	56.9	4.2e+01	2.7e-21	Measured	1.2e-19	2.8e-20	4.19
L1:PEM-CS_ACC_BEAMTUBE_MCTUBE_Y_DQ	37.9	1.6e+01	9.3e-21	Upper Limit	1.5e-19	4.1e-20	3.58
L1:PEM-EY_ACC_BSC5_ETMY_Z_DQ	32.7	1.3e+01	1.5e-20	Upper Limit	2.0e-19	5.9e-20	3.48
L1:PEM-EY_MIC_VEA_PLUSY_DQ	48.2	9.2e+01	1.2e-21	Measured	1.1e-19	3.1e-20	3.39
L1:PEM-CS_ACC_ISCT1_REFL_Y_DQ	38.8	1.0e+01	6.9e-21	Upper Limit	7.1e-20	4.0e-20	1.78
L1:PEM-EX_ACC_BSC4_ETMX_Z_DQ	26.8	3.5e+00	4.9e-20	Upper Limit	1.7e-19	1.1e-19	1.56
L1:PEM-EX_ACC_OPLEV_ETMX_Y_DQ	37.2	3.6e+00	2.1e-20	Upper Limit	7.5e-20	4.9e-20	1.52
L1:PEM-CS_ACC_LVEAFLOOR_HAM1_Z_DQ	24.5	1.7e+00	9.8e-20	Upper Limit	1.7e-19	1.2e-19	1.42
L1:PEM-EX_MIC_EBAY_RACKS_DQ	21.6	2.0e+01	1.2e-20	Upper Limit	2.5e-19	1.8e-19	1.37
L1:PEM-EX_ACC_VEA_FLOOR_Z_DQ	26.8	3.5e+00	3.9e-20	Upper Limit	1.4e-19	1.0e-19	1.31
L1:PEM-CS_ACC_BSC1_ITMY_Y_DQ	23.9	1.4e+01	1.1e-20	Upper Limit	1.5e-19	1.3e-19	1.21
L1:PEM-CS_ACC_HAM2_PRM_Y_DQ	34.6	3.9e+00	1.5e-20	Upper Limit	5.8e-20	5.0e-20	1.16
L1:PEM-CS_ACC_PSL_PERISCOPE_X_DQ	39.9	1.4e+00	3.4e-20	Upper Limit	4.6e-20	4.2e-20	1.10
L1:PEM-EY_ACC_EBAY_FLOOR_Z_DQ	44.2	1.3e+01	2.8e-21	Upper Limit	3.6e-20	3.5e-20	1.03

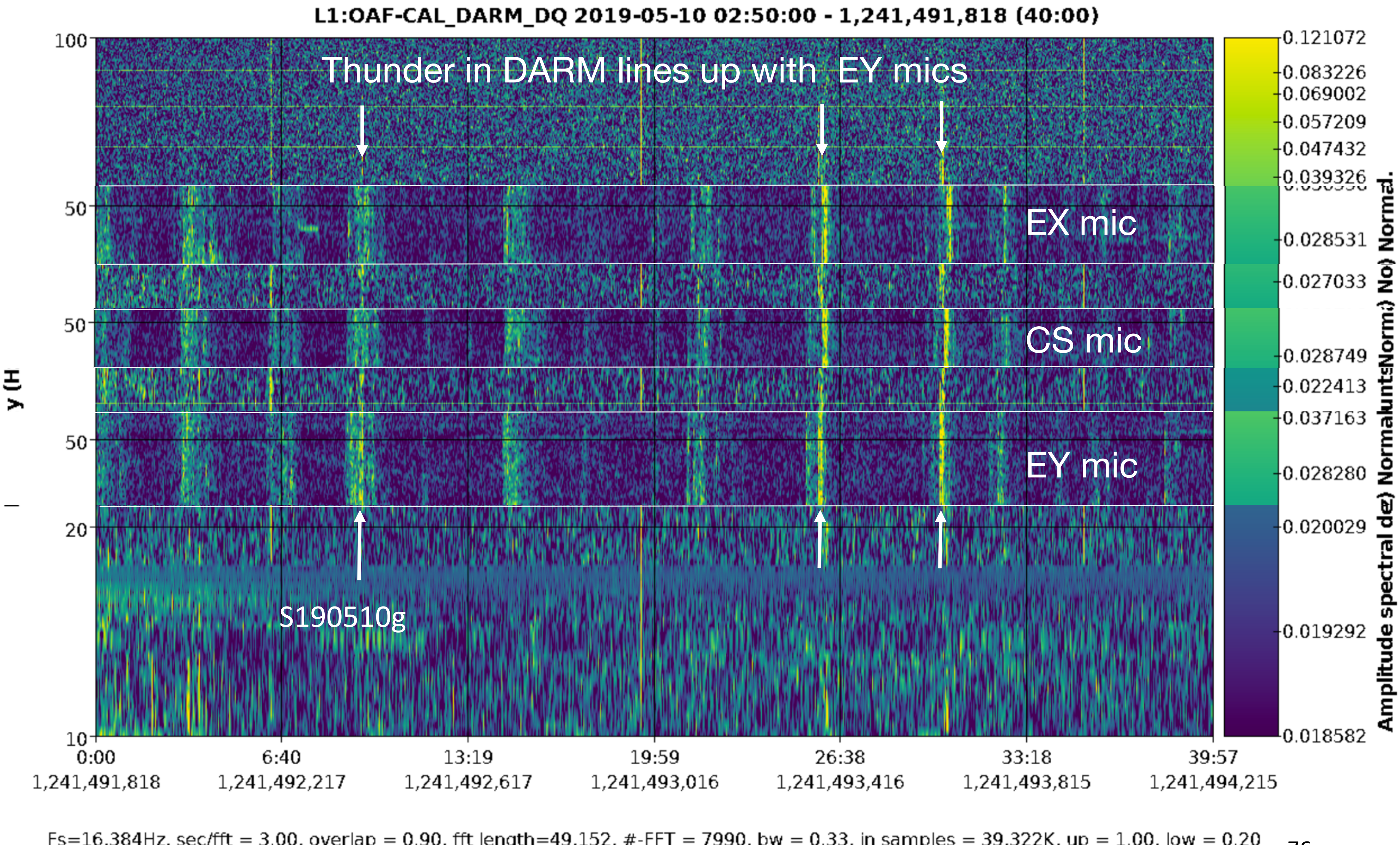

L1:PEM-CS_MIC_LVEA_BS_DQ 2019-05-10 01:00:00 - 1,241,485,218 (2:30:00)
"0125 A very loud thunderclap shook the building"
CS
Frequency (Hz)
Amplitude spectral density (Counts / √Hz) Normalized.
Fs=16,384Hz, sec/fft = 0.30, overlap = 0.50, fft length=4,915, #-FFT = 59990, bw = 3, in samples = 147,456K, up = 1.00, low = 0.20


L1:PEM-EX_MIC_VEA_PLUSX_DQ 2019-05-10 01:00:00 - 1,241,485,218 (2:30:00)
EX
Frequency (Hz)
Amplitude spectral density (Counts / √Hz) Normalized.
Fs=16,384Hz, sec/fft = 0.30, overlap = 0.50, fft length=4,915, #-FFT = 59990, bw = 3, in samples = 147,456K, up = 1.00, low = 0.20


L1:PEM-EY_MIC_VEA_PLUSY_DQ 2019-05-10 01:00:00 - 1,241,485,218 (2:30:00)
EY
S190510g
Frequency (Hz)
Amplitude spectral density (Counts / √Hz) Normalized.
Fs=16,384Hz, sec/fft = 0.30, overlap = 0.50, fft length=4,915, #-FFT = 59990, bw = 3, in samples = 147,456K, up = 1.00, low = 0.20


L1:PEM-EY_ACC_BEAMTUBE_MAN_Y_DQ 2019-05-10 01:00:00 - 1,241,485,218 (2:30:00)
EY
S190510g
Frequency (Hz)
Amplitude spectral density (Counts / √Hz) Normalized.
Fs=4,096Hz, sec/fft = 0.30, overlap = 0.50, fft length=1,228, #-FFT = 59999, bw = 3, in samples = 36,864K, up = 1.00, low = 0.20


L1:OAF-CAL_DARM_DQ 2019-05-10 02:50:00 - 1,241,491,818 (40:00)
Thunder appearing in DARM
S190510g
Frequency (Hz)
100
50
20
10
0:00
1,241,491,818
6:40
1,241,492,217
13:19
1,241,492,617
19:59
1,241,493,016
26:38
1,241,493,416
33:18
1,241,493,815
39:57
1,241,494,215
Amplitude spectral density (Counts / √Hz) Normalized.
0.121072
0.083226
0.069002
0.057209
0.047432
0.039326
0.032605
0.027033
0.022413
0.021588
0.020794
0.020029
0.019292
0.018582
Fs=16,384Hz, sec/fft = 3.00, overlap = 0.90, fft length=49,152, #-FFT = 7990, bw = 0.33, in samples = 39,322K, up = 1.00, low = 0.20


L1:OAF-CAL_DARM_DQ 2019-05-10 02:50:00 - 1,241,491,818 (40:00)
Thunder in DARM lines up with EY mics
EX mic
CS mic
EY mic
S190510g
100
50
50
50
20
10
0:00
1,241,491,818
6:40
1,241,492,217
13:19
1,241,492,617
19:59
1,241,493,016
26:38
1,241,493,416
33:18
1,241,493,815
39:57
1,241,494,215
0.121072
0.083226
0.069002
0.057209
0.047432
0.039326
0.028531
0.027033
0.028749
0.022413
0.037163
0.028280
0.020029
0.019292
0.018582
Fs=16,384Hz, sec/fft = 3.00, overlap = 0.90, fft length=49,152, #-FFT = 7990, bw = 0.33, in samples = 39,322K, up = 1.00, low = 0.20

Reports until 22:07, Wednesday 01 May 2019

H1 PEM (DetChar) Link

robert.schofield@LIGO.ORG - posted 22:07, Wednesday 01 May 2019 (48912)

HVAC noise in DARM roughly consistent with prediction for septum from PEM injections

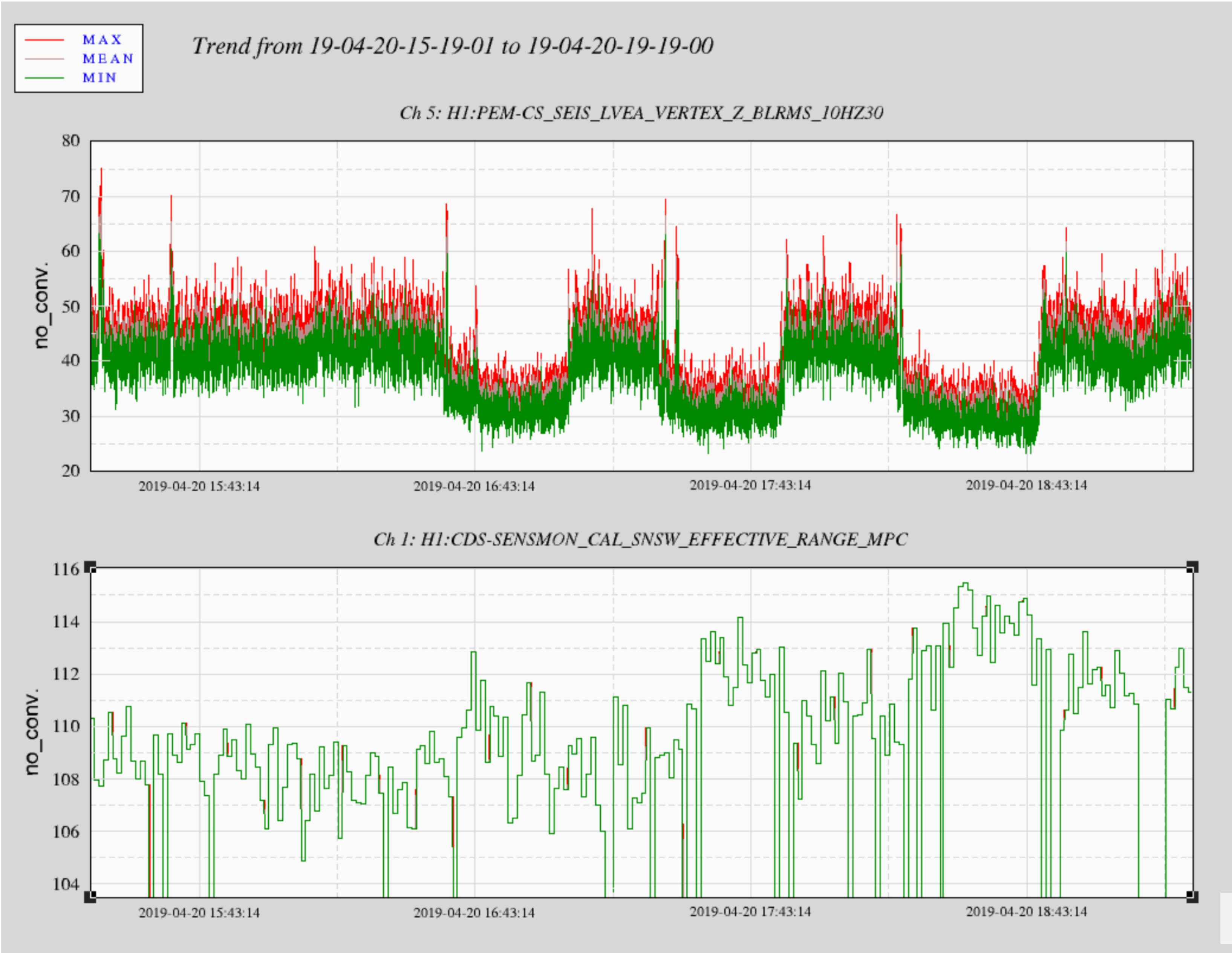
Philippe, Sharan, Kara, Anamaria, Robert

The HVAC reduces our range by 3 or 4 MPc (https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=48649). Shutting down the various stations showed that the corner station is the worst culprit but there also appears to be some coupling at EX. Figure 1 shows that the HVAC is affecting DARM in the 30-90 Hz region. The lower plot in Figure 1 shows that, at the corner station, the HVAC increases ground and septum motion above a few Hz. This is in the frequency band that we can shake with the big shaker, so we would hope to be able to reproduce the HVAC effect, though, of course, local shaking would differ some from the more global shaking produced by the HVAC.

A preview of the LVEA vibration coupling summary from the recent PEM injection program suggests that the strongest coupling site in the 30-90 Hz band is in the HAM5/6 area (Figure 2a). Impulse injections narrow the coupling site down to the septum (https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=48886). Figure 2b suggests that the noise from the motion of the septum when the HVAC is on would be a factor of about 3 below the DARM floor. This would be enough to produce the several percent change in DARM when the HVAC was turned off and the septum motion was reduced by a factor of 1.5 to 2.

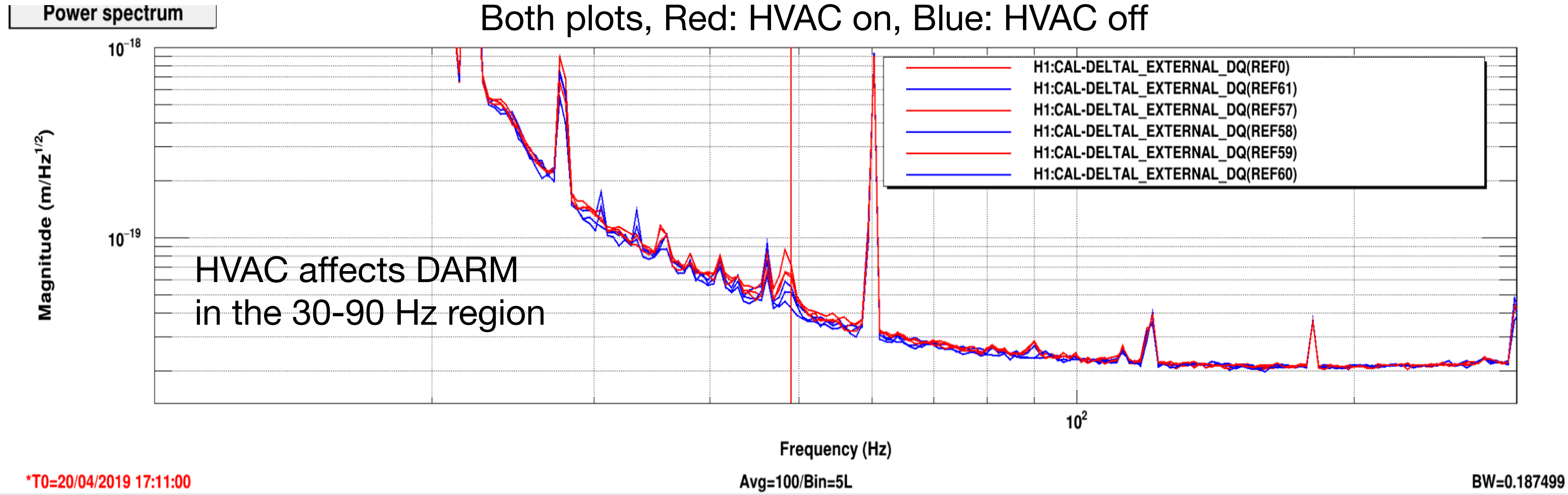
Non-image files attached to this report

- Figure1-HVAC-effect-DARM-and-sensors.pdf
- Figure2-Vibration-contribution-estimate.pdf



MAX
MEAN
MIN
Trend from 19-04-20-15-19-01 to 19-04-20-19-19-00
Ch 5: H1:PEM-CS_SEIS_LVEA_VERTEX_Z_BLRMS_10HZ30
no_conv.
80
70
60
50
40
30
20
2019-04-20 15:43:14
2019-04-20 16:43:14
2019-04-20 17:43:14
2019-04-20 18:43:14
Ch 1: H1:CDS-SENSMON_CAL_SNSW_EFFECTIVE_RANGE_MPC
no_conv.
116
114
112
110
108
106
104
2019-04-20 15:43:14
2019-04-20 16:43:14
2019-04-20 17:43:14
2019-04-20 18:43:14

Both plots, Red: HVAC on, Blue: HVAC off



HVAC affects seismometer and accelerometer signals above 5 Hz

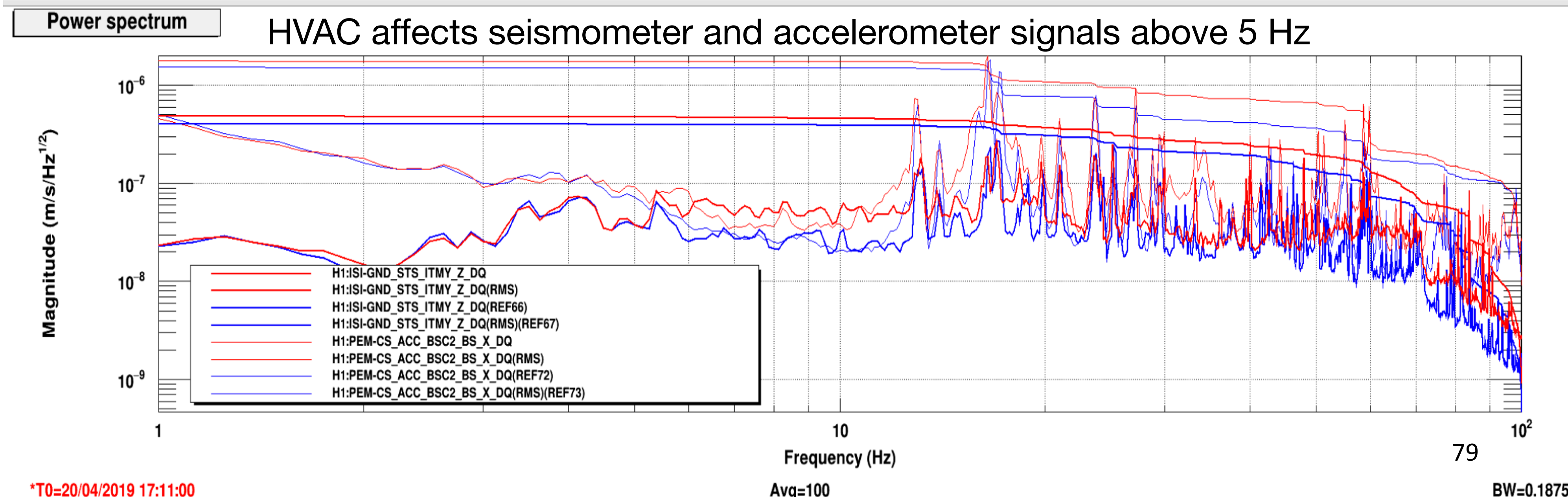
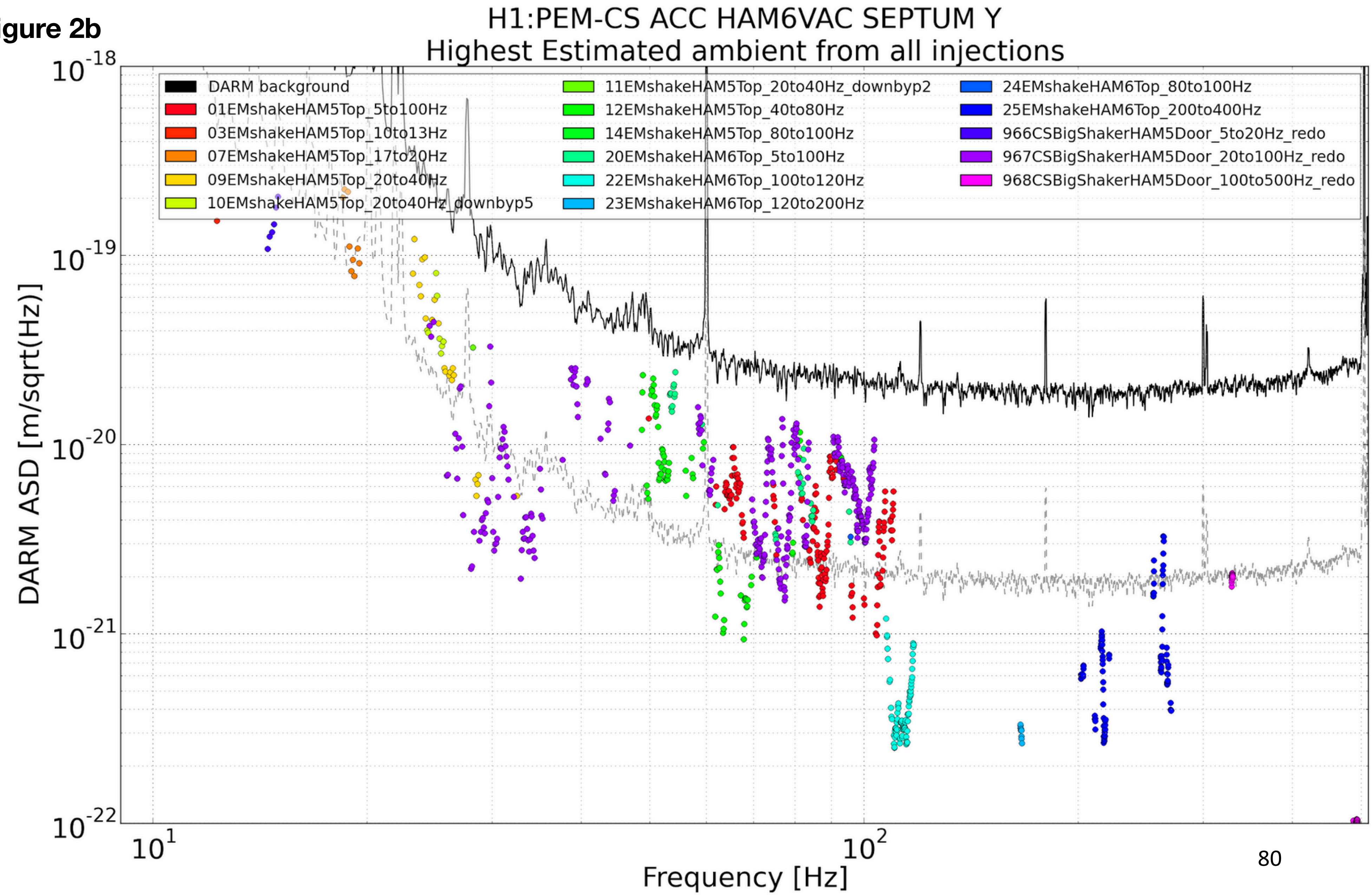


Figure 2b



H1:PEM-CS ACC HAM6VAC SEPTUM Y
Highest Estimated ambient from all injections
DARM background
01EMshakeHAM5Top_5to100Hz
03EMshakeHAM5Top_10to13Hz
07EMshakeHAM5Top_17to20Hz
09EMshakeHAM5Top_20to40Hz
10EMshakeHAM5Top_20to40Hz_downbyp5
11EMshakeHAM5Top_20to40Hz_downbyp2
12EMshakeHAM5Top_40to80Hz
14EMshakeHAM5Top_80to100Hz
20EMshakeHAM6Top_5to100Hz
22EMshakeHAM6Top_100to120Hz
23EMshakeHAM6Top_120to200Hz
24EMshakeHAM6Top_80to100Hz
25EMshakeHAM6Top_200to400Hz
966CSBigShakerHAM5Door_5to20Hz_redo
967CSBigShakerHAM5Door_20to100Hz_redo
968CSBigShakerHAM5Door_100to500Hz_redo
DARM ASD [m/sqrt(Hz)]
10^{-18}
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{1}
10^{2}
Frequency [Hz]

Reports until 09:37, Tuesday 28 May 2019

H1 AOS Link

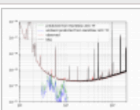
sharan.banagiri@LIGO.ORG - posted 09:37, Tuesday 28 May 2019 (49495)

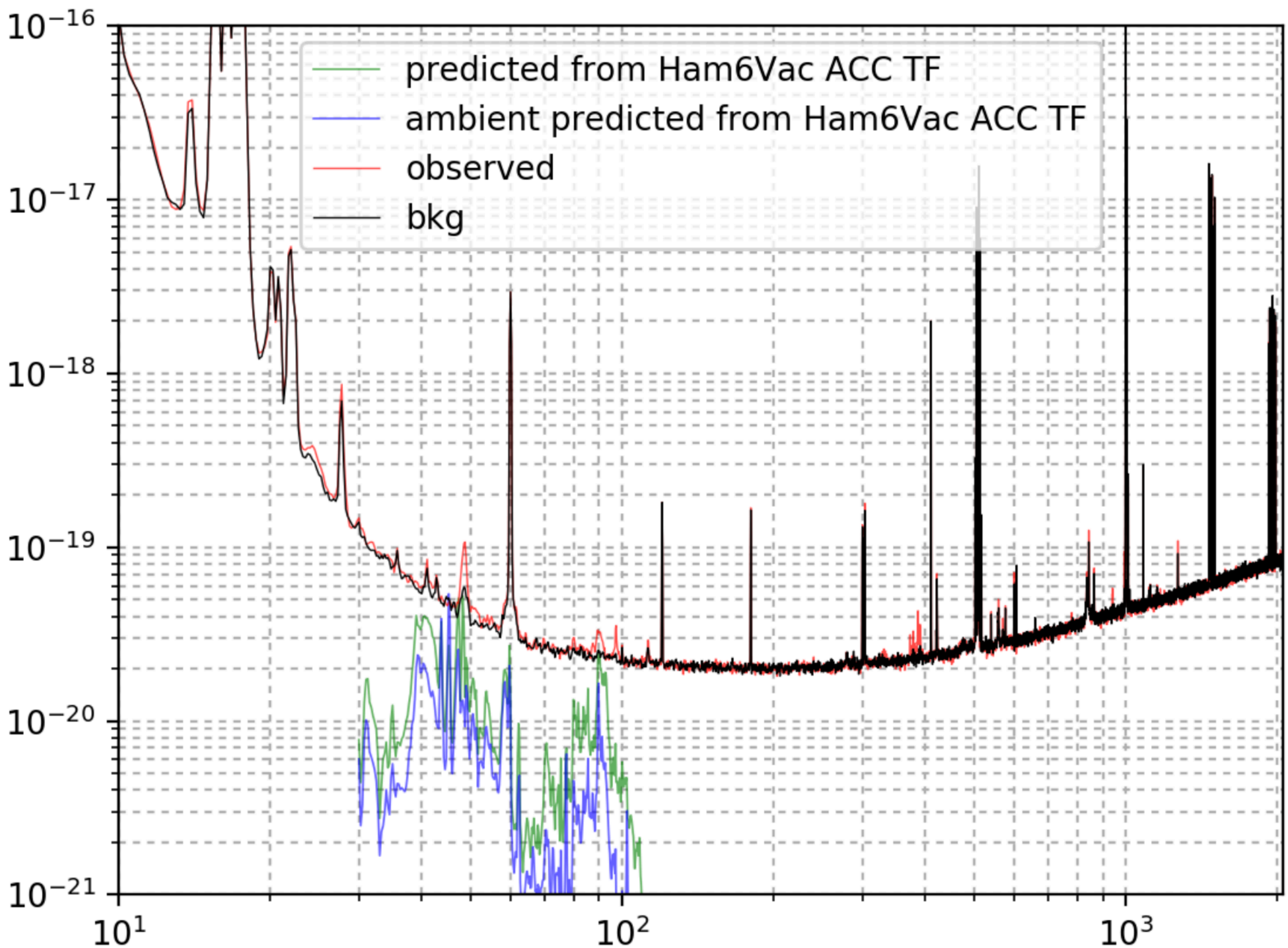
PEM with Rain using HAM6 Vac accelerometer

S Banagiri, P Covas, R Schofield

We looked into the adhoc rain pem injection in more detail (mentioned here before), using transfer function measurements by Philippe Nguyen with the HAM6 Vac accelerometer. Quantitatively, these predictions show that we somewhat underestimate the noise in DARM during rain using only the HAM6 accelerometer prediction. I attach a plot of a DARM background ASD and DARM during rain plotted in black and red respectively using about 5 minutes of data. Also plotted are the predictions of DARM noise in the 30 - 100 Hz band using the HAM6 Vac accelerometer. The blue curve is the ambient noise prediction and the green curve is the prediction during rain.

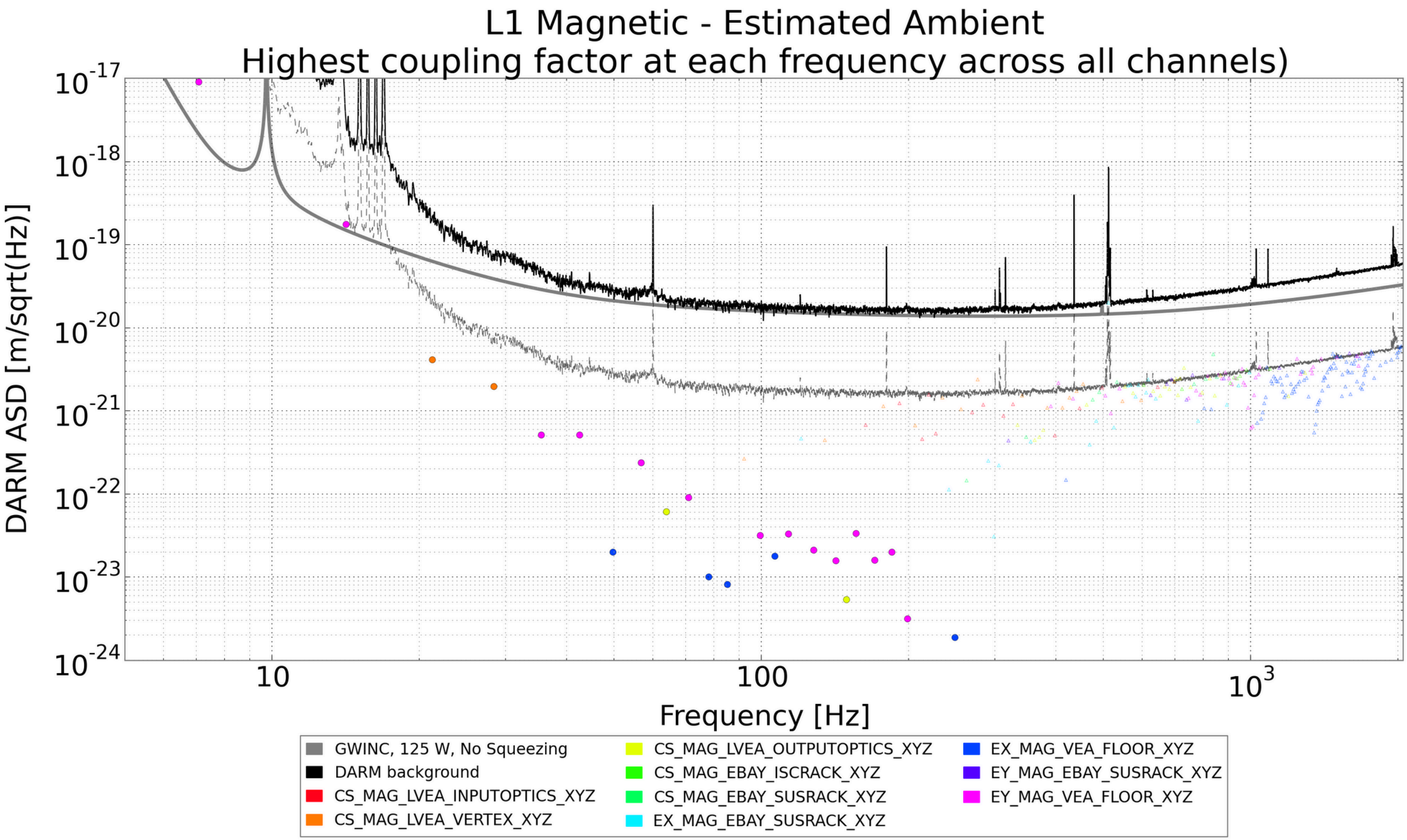
Images attached to this report



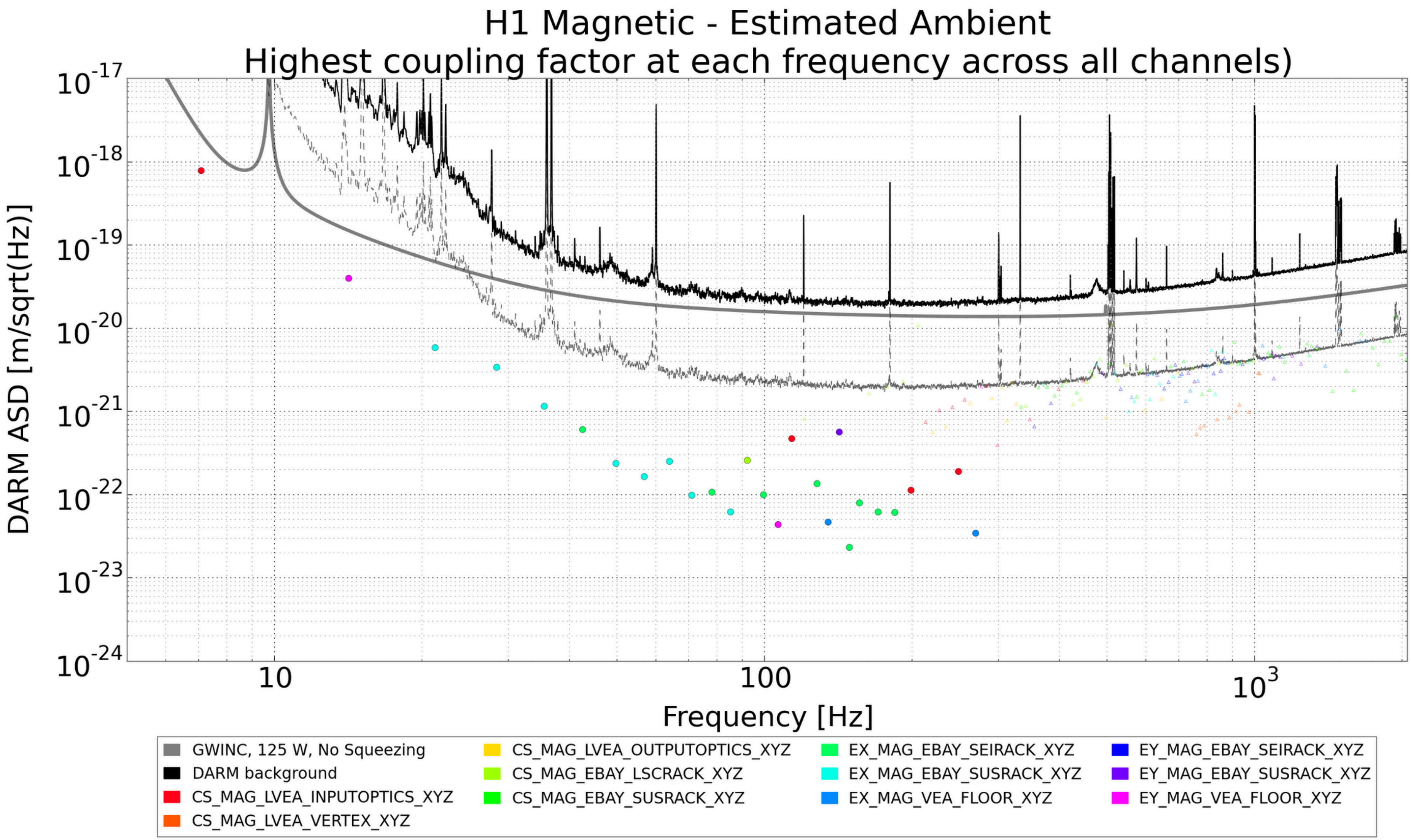


predicted from Ham6Vac ACC TF
ambient predicted from Ham6Vac ACC TF
observed
bkg
10^{-16}
10^{-17}
10^{-18}
10^{-19}
10^{-20}
10^{-21}
10^{1}
10^{2}
10^{3}

Introduction
A. Vibration coupling, worst sites
  1) LLO EX transmission monitor
  2) Next worst sites at LLO are EY and HAM5/6 and, at LHO, HAM5/6 and the PSL
  3) At both sites, HAM5/6 coupling is likely at the septum
  4) EY coupling at LLO is likely in the manifold, at LHO, it may in the ETMY chamber
  5) HAM5/6 coupling at the septum window?
    Other beam spots on LLO HAM6
    OMC REFL beam not the cause of the main HAM5/6 scattering
    HAM6 witness search at LLO
  6) IO jitter coupling at both sites
  7) Comparison of EY and EX in-lock photos
  8) Shaker injections at EY produce noise similar to some anthropogenic noise
  9) Other vibration coupling
    Beamtube shaking
    Coupling at LHO BS chamber and at the reduction flanges by the optical lever
    48 Hz peak at LHO
    Reduction of 58 Hz chiller peak at LHO:
  10) Vibration coupling not seen (at least 10 below DARM)
  11) Coupling estimates from PEM injections correctly predict environmental coupling
    LLO DARM glitch near S190510g is correctly predicted from PEM injection coupling functions.
    Range reduction from LHO HVAC is roughly predicted from estimates for HAM5/6.
    Range reduction from rain at LHO is roughly consistent with PEM coupling functions
    Range reduction from wind at LHO is roughly consistent with PEM coupling functions.
B. Magnetic Coupling
C. RF Coupling
D. Site activities

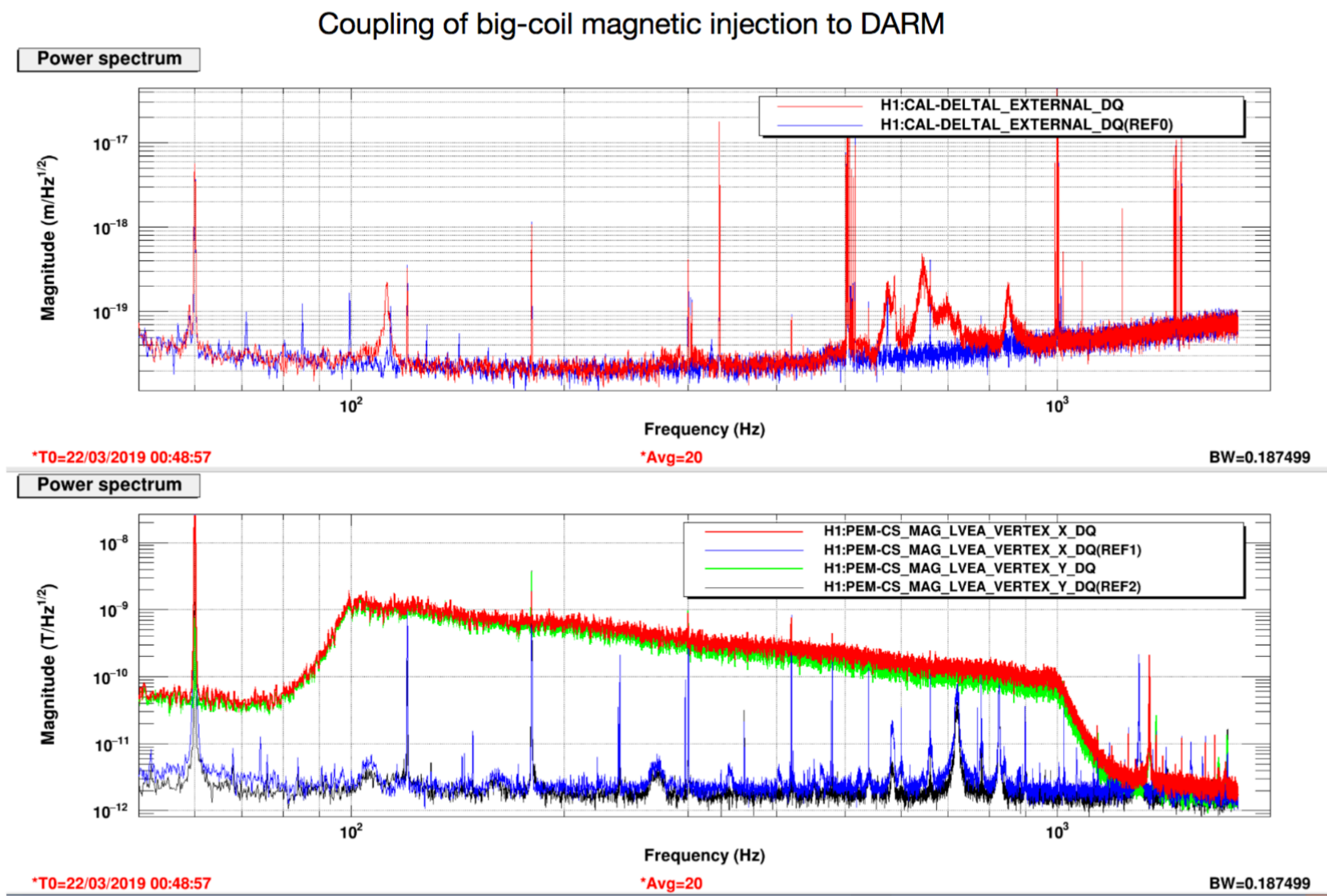


Ambient estimates are made by multiplying coupling factors by injection-free sensor levels. CIRCLES indicate estimates from measured coupling factors, i.e. where the injection signal was seen in the sensor and in DARM. TRIANGLES represent upper limit coupling factors, i.e. where a signal was seen in the sensor but not in DARM. For some channels, at certain frequencies the ambient estimates are upper limits because the ambient level is below the sensor noise floor.



Ambient estimates are made by multiplying coupling factors by injection-free sensor levels. CIRCLES indicate estimates from measured coupling factors, i.e. where the injection signal was seen in the sensor and in DARM. TRIANGLES represent upper limit coupling factors, i.e. where a signal was seen in the sensor but not in DARM. For some channels, at certain frequencies the ambient estimates are upper limits because the ambient level is below the sensor noise floor.

a



Coupling of big-coil magnetic injection to DARM
Power spectrum
H1:CAL-DELTAL_EXTERNAL_DQ
H1:CAL-DELTAL_EXTERNAL_DQ(REF0)
Magnitude (m/Hz^1/2)
10^-17
10^-18
10^-19
10^2
10^3
Frequency (Hz)
*T0=22/03/2019 00:48:57
*Avg=20
BW=0.187499
Power spectrum
H1:PEM-CS_MAG_LVEA_VERTEX_X_DQ
H1:PEM-CS_MAG_LVEA_VERTEX_X_DQ(REF1)
H1:PEM-CS_MAG_LVEA_VERTEX_Y_DQ
H1:PEM-CS_MAG_LVEA_VERTEX_Y_DQ(REF2)
Magnitude (T/Hz^1/2)
10^-8
10^-9
10^-10
10^-11
10^-12
10^2
10^3
Frequency (Hz)
*T0=22/03/2019 00:48:57
*Avg=20
BW=0.187499

Introduction

A. Vibration coupling, worst sites

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- **3) At both sites, HAM5/6 coupling is likely at the septum**
- **4) EY coupling at LLO is likely in the manifold, at LHO, it may in the ETMY chamber**
- **5) HAM5/6 coupling at the septum window?**
  - *Other beam spots on LLO HAM6*
  - *OMC REFL beam not the cause* of the main HAM5/6 scattering
  - *HAM6 witness search at LLO*
- **6) IO jitter coupling at both sites**
- **7) Comparison of EY and EX in-lock photos**
- **8) Shaker injections at EY produce noise similar to some anthropogenic noise**
- **9) Other vibration coupling**
  - *Beamtube shaking*
  - *Coupling at LHO BS chamber and at the reduction flanges by the optical lever*
  - *48 Hz peak at LHO*
  - *Reduction of 58 Hz chiller peak at LHO*:
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  - *Range reduction from wind* at LHO is roughly consistent with PEM coupling functions.

B. Magnetic Coupling

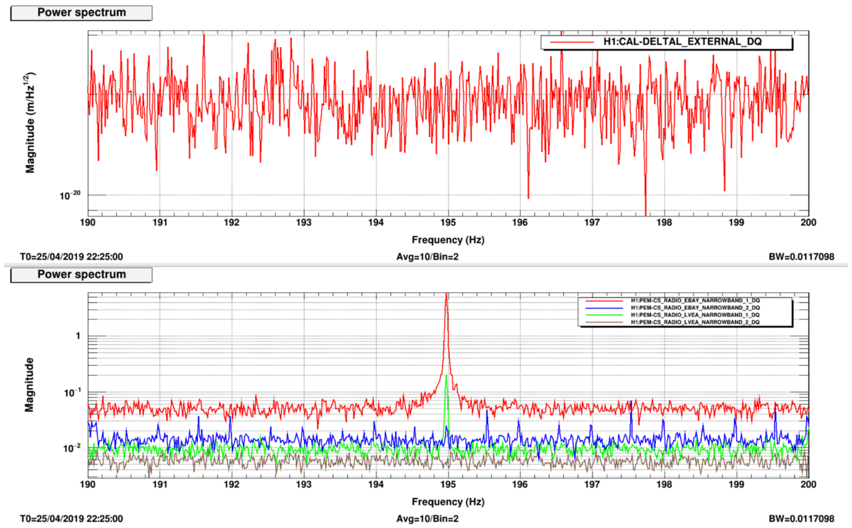
C. RF Coupling

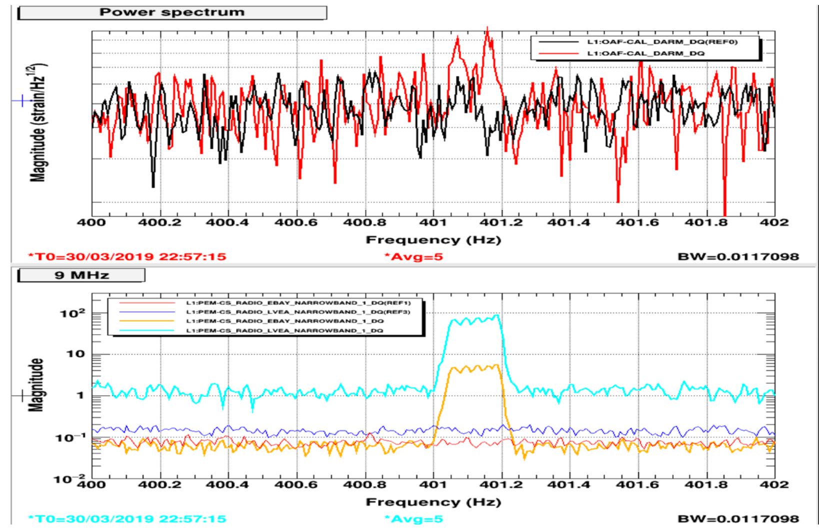
D. Site activities

LHO

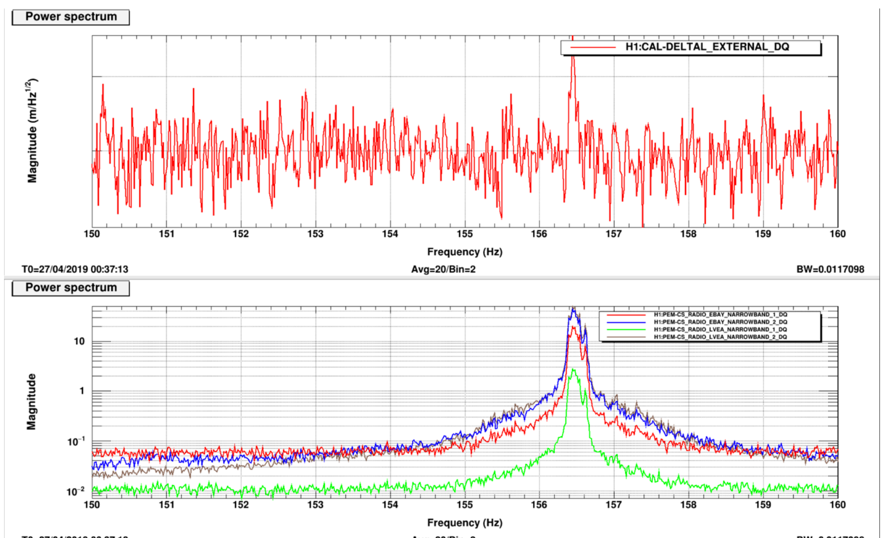
LLO

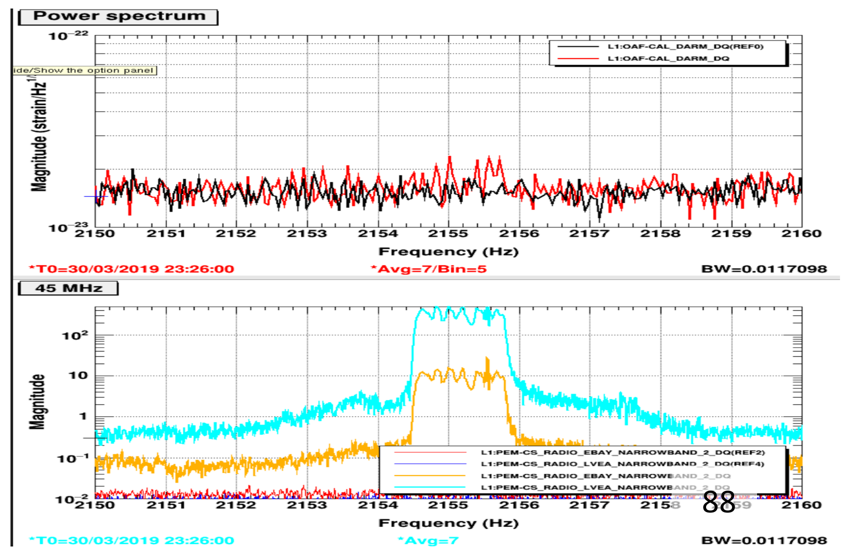
9 MHz





45 MHz





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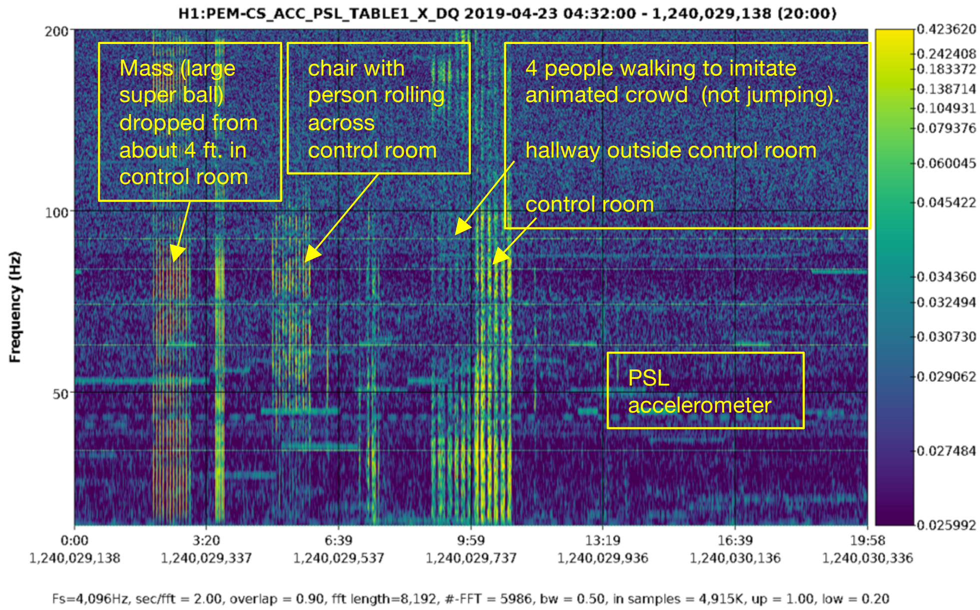
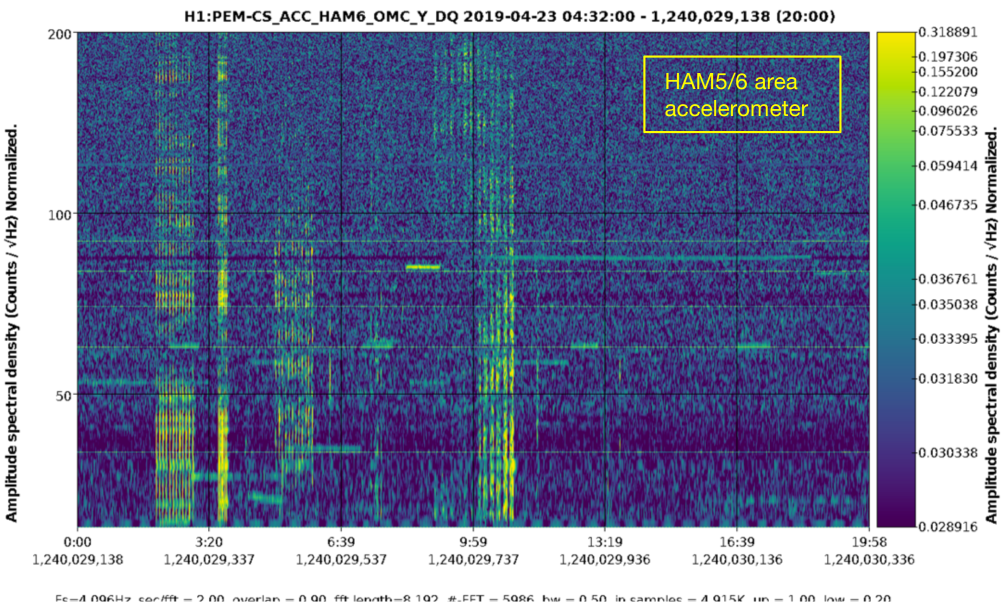
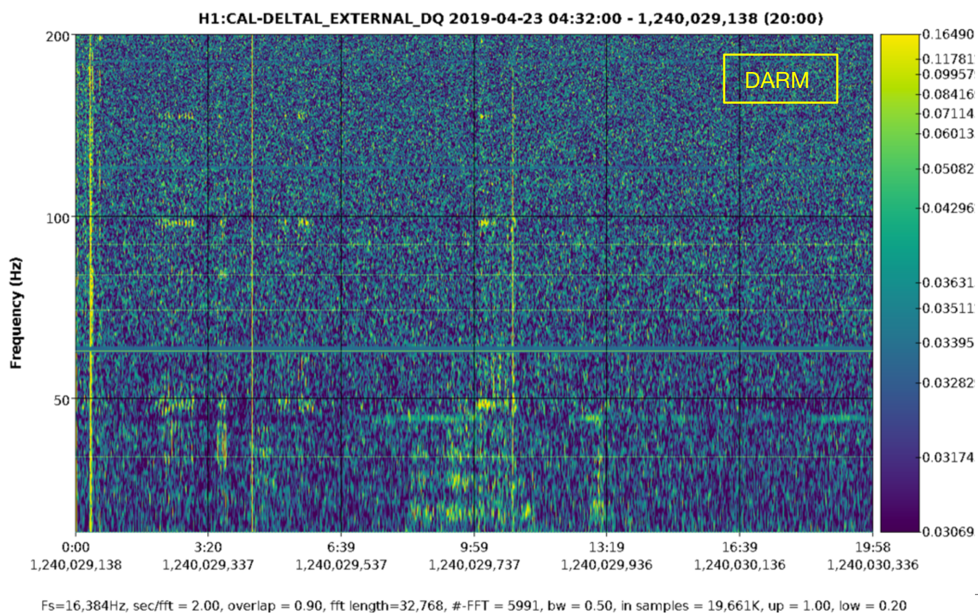
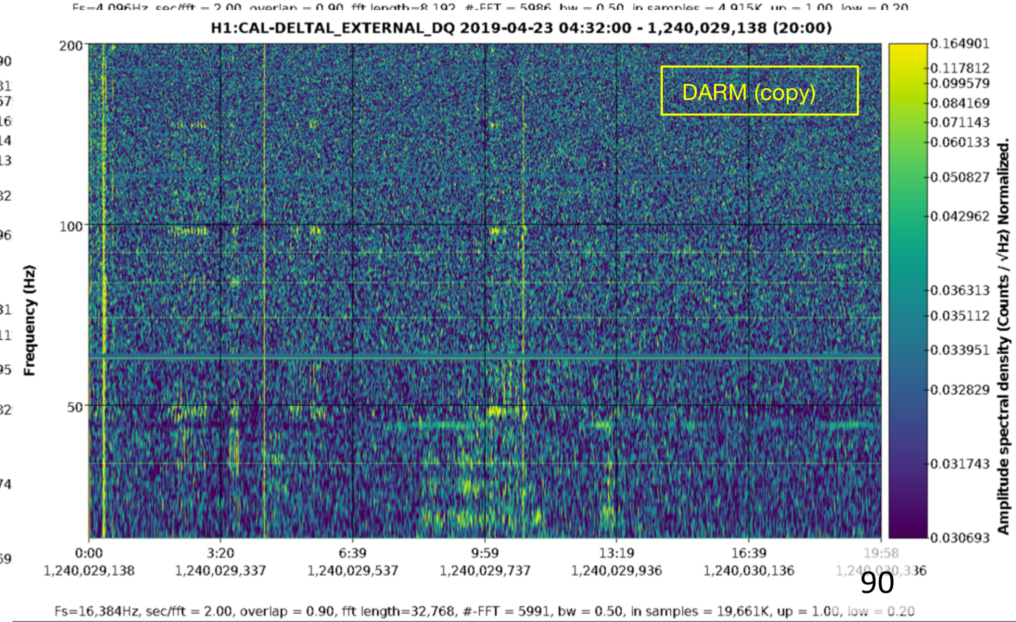
C. RF Coupling
D. Site activities


H1:PEM-CS_ACC_PSL_TABLE1_X_DQ 2019-04-23 04:32:00 - 1,240,029,138 (20:00)
Mass (large super ball) dropped from about 4 ft. in control room
chair with person rolling across control room
4 people walking to imitate animated crowd (not jumping).
hallway outside control room
control room
PSL accelerometer
Frequency (Hz)
Amplitude spectral density (Counts / √Hz) Normalized.
0:00 1,240,029,138
3:20 1,240,029,337
6:39 1,240,029,537
9:59 1,240,029,737
13:19 1,240,029,936
16:39 1,240,030,136
19:58 1,240,030,336
Fs=4,096Hz, sec/fft = 2.00, overlap = 0.90, fft length=8,192, #-FFT = 5986, bw = 0.50, in samples = 4,915K, up = 1.00, low = 0.20


H1:PEM-CS_ACC_HAM6_OMC_Y_DQ 2019-04-23 04:32:00 - 1,240,029,138 (20:00)
HAM5/6 area accelerometer
Amplitude spectral density (Counts / √Hz) Normalized.
0:00 1,240,029,138
3:20 1,240,029,337
6:39 1,240,029,537
9:59 1,240,029,737
13:19 1,240,029,936
16:39 1,240,030,136
19:58 1,240,030,336


H1:CAL-DELTAL_EXTERNAL_DQ 2019-04-23 04:32:00 - 1,240,029,138 (20:00)
DARM
Frequency (Hz)
0:00 1,240,029,138
3:20 1,240,029,337
6:39 1,240,029,537
9:59 1,240,029,737
13:19 1,240,029,936
16:39 1,240,030,136
19:58 1,240,030,336
Fs=16,384Hz, sec/fft = 2.00, overlap = 0.90, fft length=32,768, #-FFT = 5991, bw = 0.50, in samples = 19,661K, up = 1.00, low = 0.20


H1:CAL-DELTAL_EXTERNAL_DQ 2019-04-23 04:32:00 - 1,240,029,138 (20:00)
DARM (copy)
Frequency (Hz)
Amplitude spectral density (Counts / √Hz) Normalized.
0:00 1,240,029,138
3:20 1,240,029,337
6:39 1,240,029,537
9:59 1,240,029,737
13:19 1,240,029,936
16:39 1,240,030,136
Fs=16,384Hz, sec/fft = 2.00, overlap = 0.90, fft length=32,768, #-FFT = 5991, bw = 0.50, in samples = 19,661K, up = 1.00, low = 0.20

Pre-O3 PEM injections

Philippe Nguyen, Sharan Banagiri, Corey Austin, Kara Merfeld
Anamaria Effler, Robert Schofield