# PEM update

## DetChar F2F, August, 2018

I. Restoration of PEM system following install

II. More sensors near coupling sites

III. Improved PEM coupling functions

IV. Plans for BBH vetting in O3

V. Most important PEM-related commissioning

VI. Other support for astrophysical search groups

Robert Schofield, Philippe Nguyen, Kara Merfeld, Ray Frey, Jordan Palamos, UO, Anamaria Effler, Corey Austin, Terra Hardwick, Valery Frolov, LLO, and many others

# I. Restore PEM system

1. Sensors
   a. Make sure accelerometers, magnetometers, microphones, narrow band radio, broad band radio, and weather stations are connected, properly oriented and working. Trouble-shoot bad channels alng with EE shop.
   b. Get cosmic ray system working.

2. LIGOCAM Diponkar’s channel monitoring system
   a. Get software running
   b. Add new channels
   c. Establish nominal good spectra where possible
   d. Turn over maintenance to CDS (Niko at LHO)

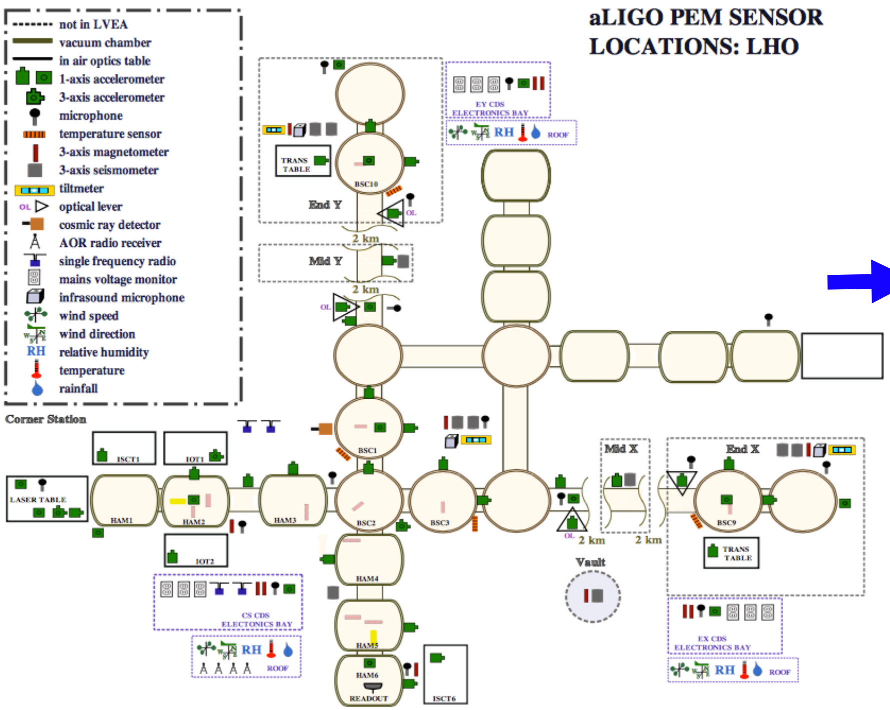
3. Jordan’s RF scanner at LHO
   a. Get it going again, solve storage problems
   b. Test for robustness
   c. Upgrade?

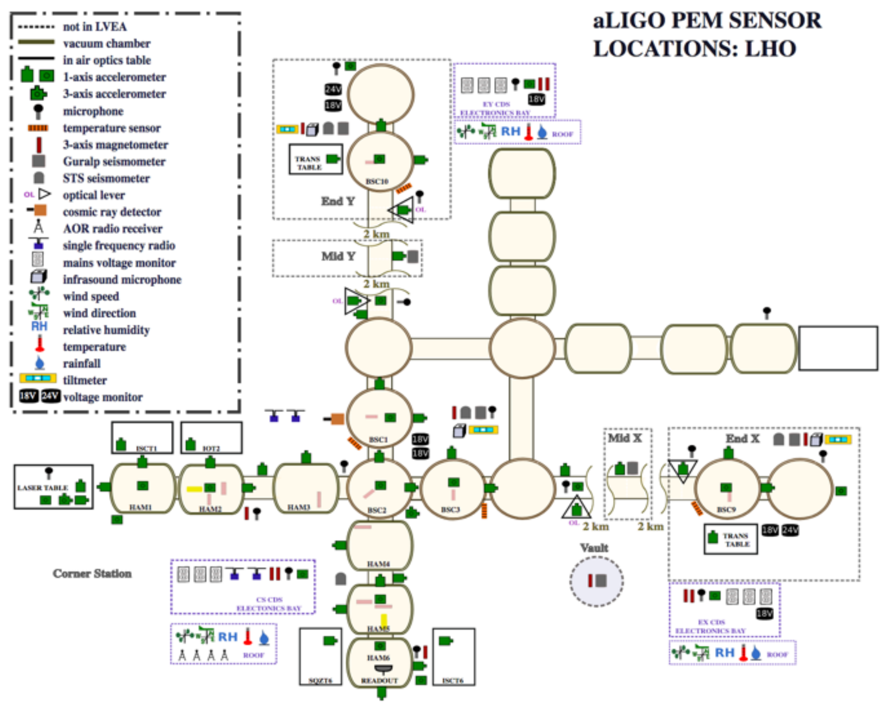
# II. More sensors near coupling sites

## $90K of proposal granted for new sensors and other PEM equipment

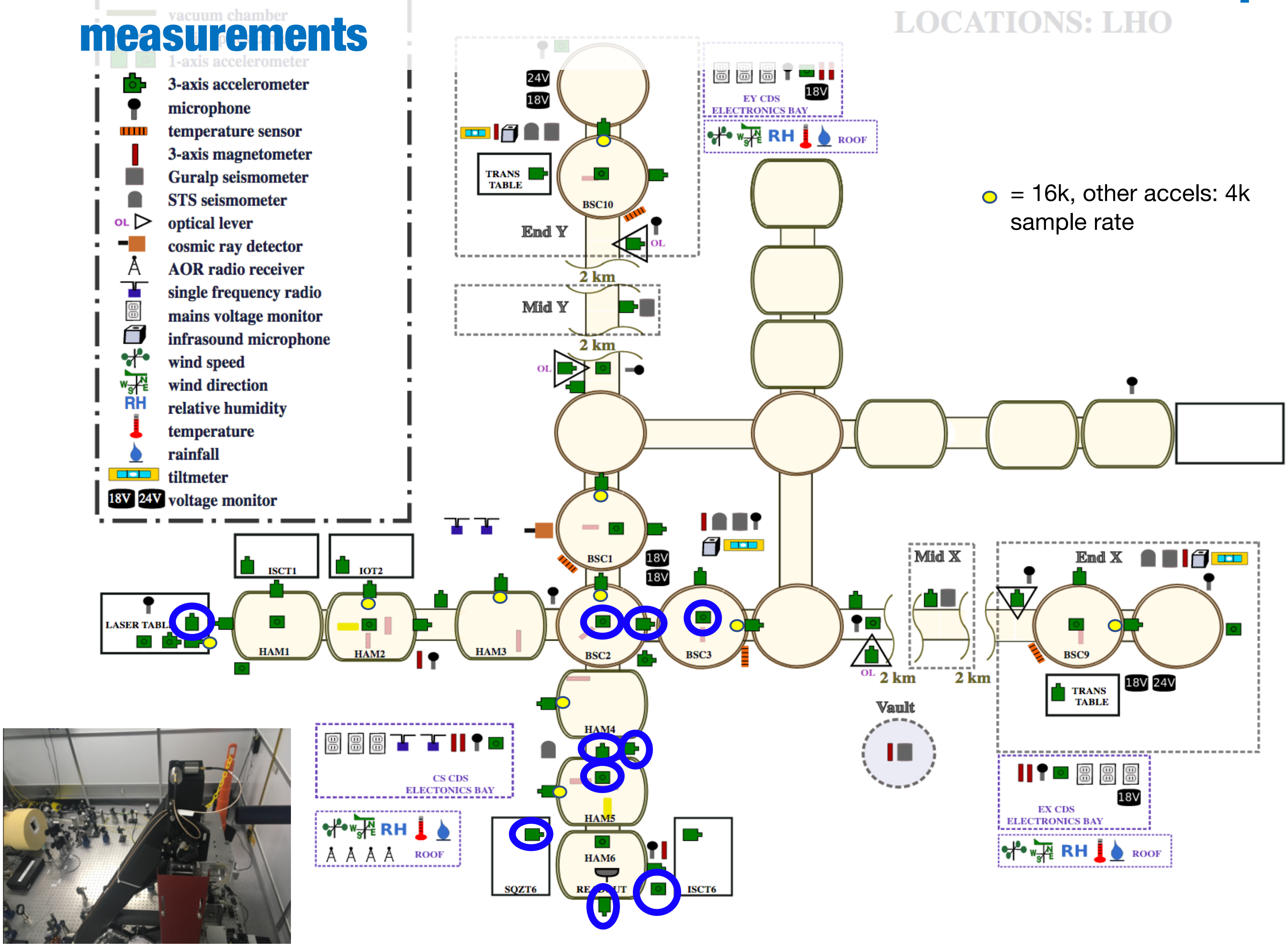
| Item | Short justification | Number | Price each | Total |
|---|---|---|---|---|
| **HIGHER PRIORITY** | | | | |
| Accelerometers, cables & signal conditioning boxes | Increase number so we can have 3 true spares each site, 6 on each PEM cart, complete instrumentation of BS, ITMS, Input and output, and some beam tube instrumentation | 10 LHO, 10 LLO | $1172 | $23,440 |
| Magnetometers | Increase number so we can have 2 on each PEM cart, and new one near each active ESD | 1 LHO, 2 LLO | $6500 | $19,500 |
| Magnetometer filter boxes | | 1 LHO, 1 LLO | Time: $1000 | $2000 |
| ADCs | For EFM, new sensors and replacing used spare channels | 2 LHO, 2 LLO | $3995 | $15,980 |
| AA chassis | | 2 LHO, 2 LLO | Time: $2000 | $8000 |
| Small accelerometer for PEM cart | For mounting on optics | 1 LHO, 1 LLO | $1000 | $2000 |
| Magnetic field generating coils | Electronics coupling now dominates, not simple permanent magnets so line injections are not reliable: we need stronger fields to do band injections | 7 LHO, 7 LLO | $1,200 | $16, 800 |
| Richards estimate of time for new injection coils | | | Time: $3000 | $4000 |
| Radio scanner | One at LLO like LHO, LLO has ALE signals that came within a factor of ten of coupling to DARM in past | 1 LLO | | $9100 |
| Richards estimate of time | | 1 LLO | $1000 | $1000 |
| | | | **TOTAL EQUIPMENT COST, high priority ITEMS** | **$86,800** |

# II. More sensors near coupling sites



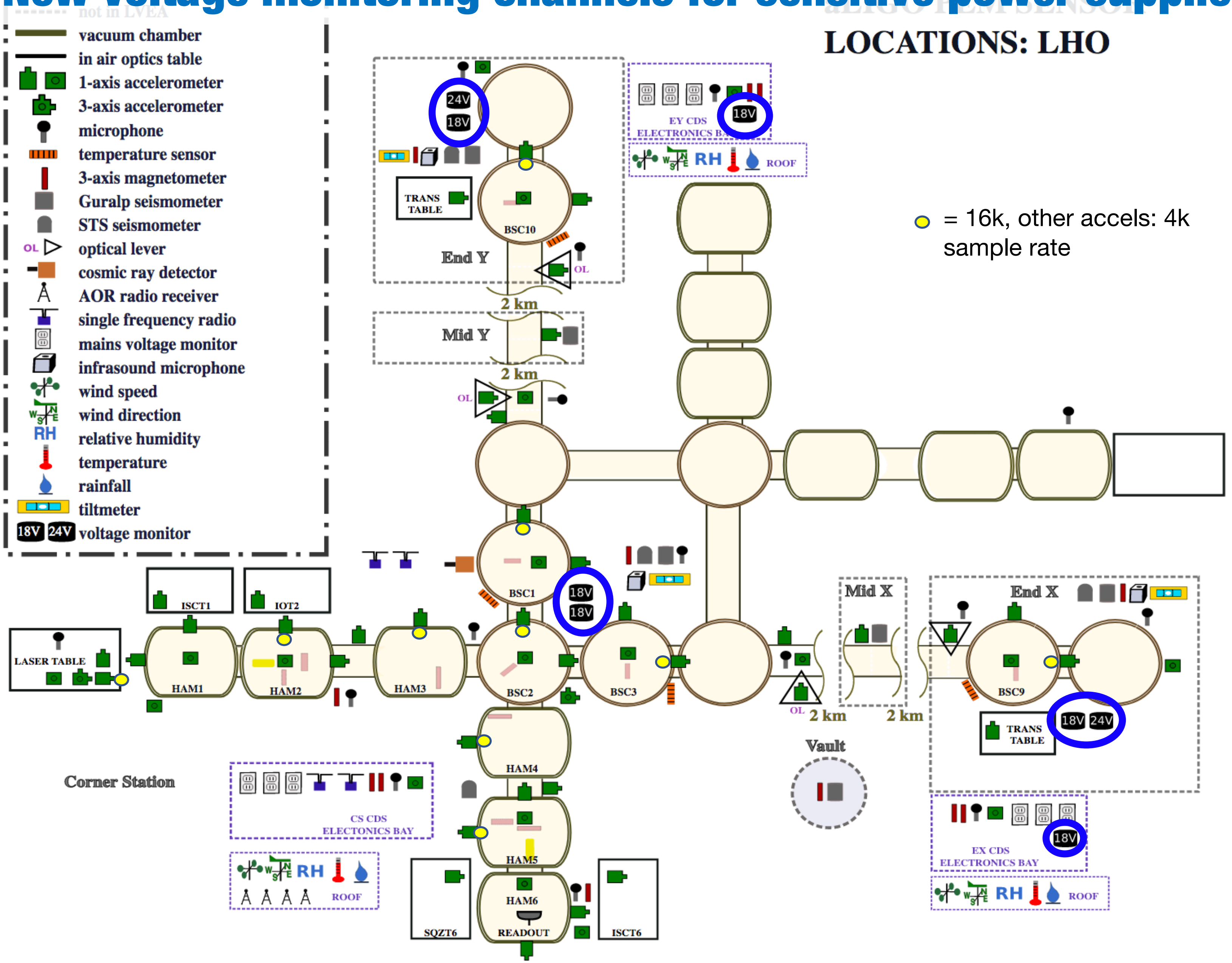



# A. Redistribution/addition of accelerometers based on O2 coupling measurements

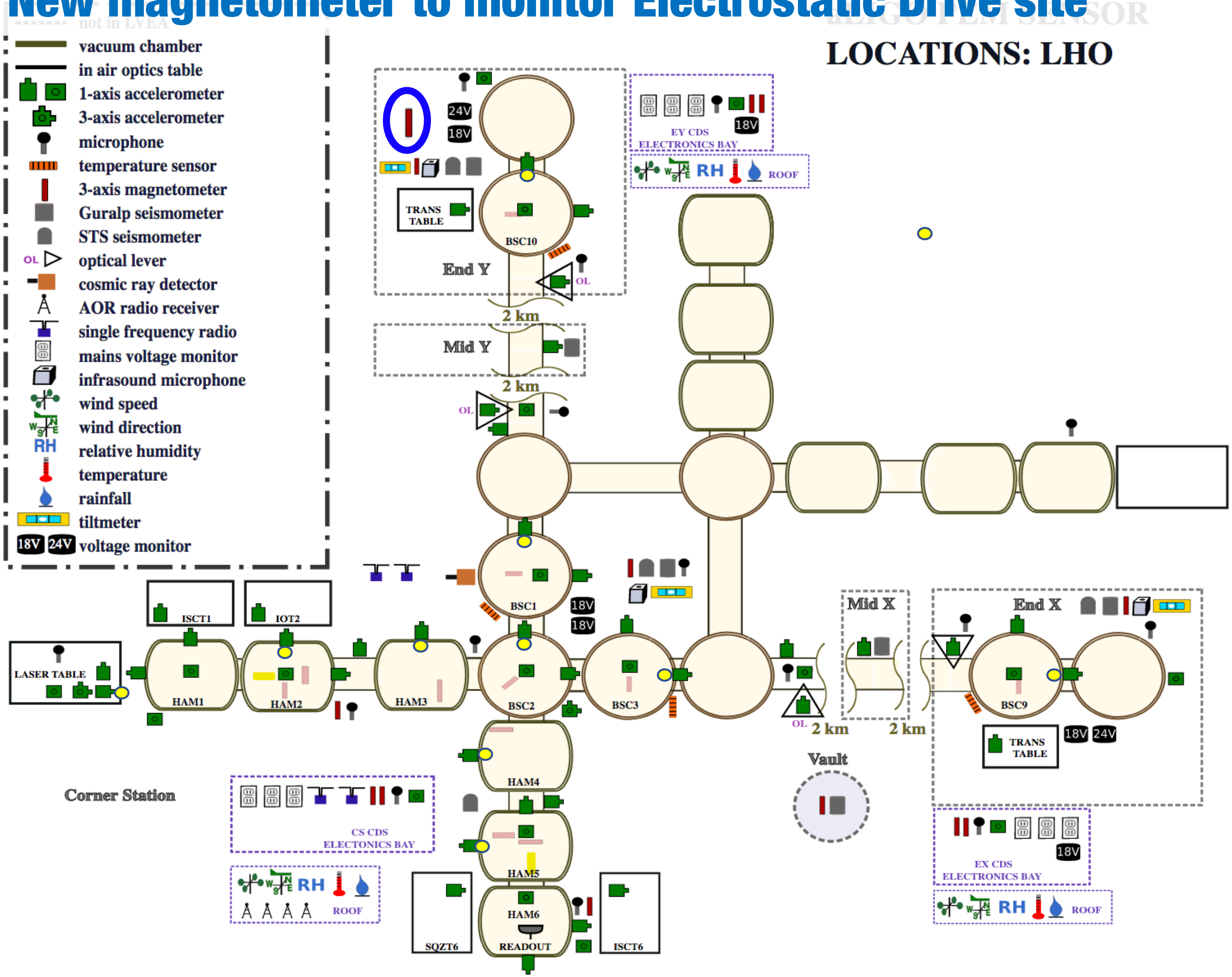



= 16k, other accels: 4k sample rate

# B. New voltage monitoring channels for sensitive power supplies



# C. New magnetometer to monitor Electrostatic Drive site



# II. More sensors near coupling sites

## Related system improvements

D. Higher sample rates on accelerometers: at least 4k (vs 2k) and additional 16k channels; note that resonances make calibrations inaccurate above 3000 Hz

E. 16 additional temporary 2k channels at the LHO corner station

F. ADCs and other CDS hardware as needed for new permanent and temporary channels

G. Quadrature sum channels for magnetometers

H. New 10KHz-2GHz radio scanner at LLO, upgrade for faster scan at LHO

I. Mid station microphones and accelerometers at LLO

# III. Improved PEM coupling functions

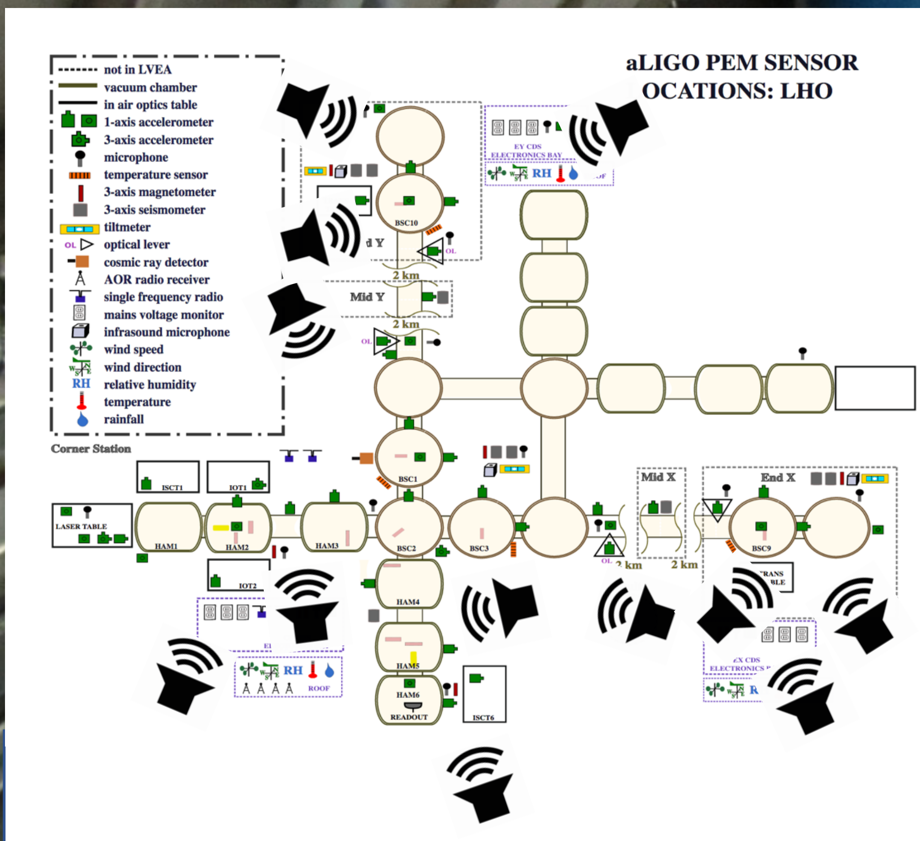
A. Philippe Nguyen and Julia Kruck's coupling function code and current further development

B. Large low-frequency shaker

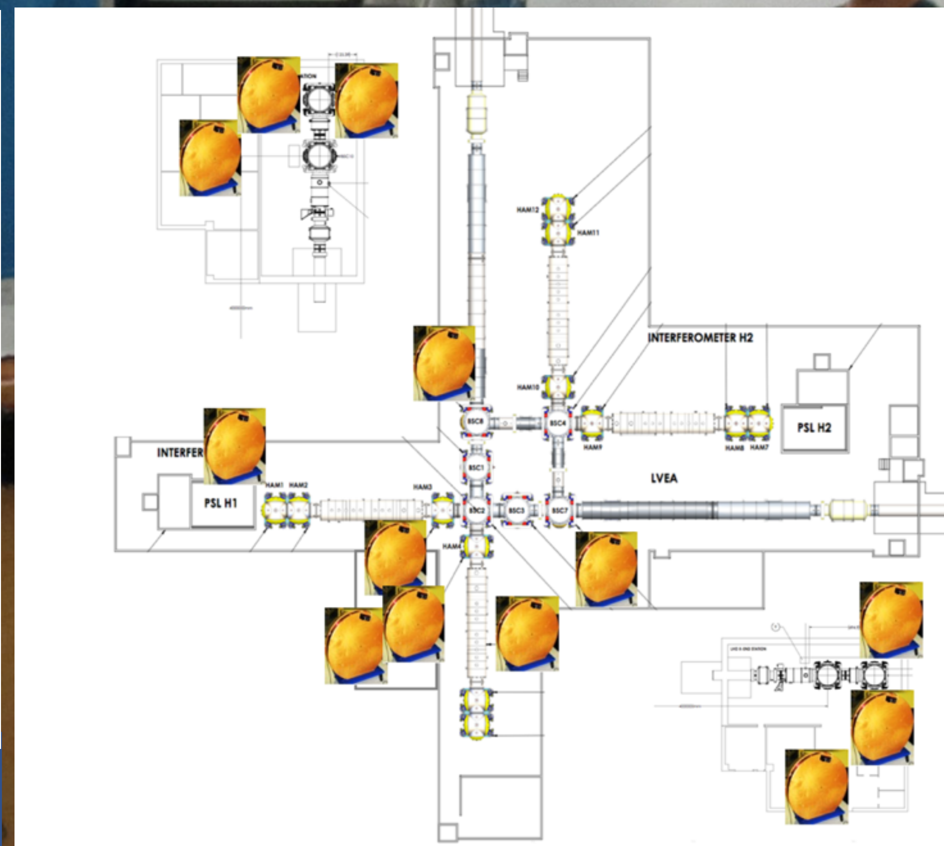
C. Development of higher-field magnetic injections so we can do more than line injections.

# A. Philippe Nguyen and Julia Kruck's code produces a single coupling function for every sensor from multiple injections

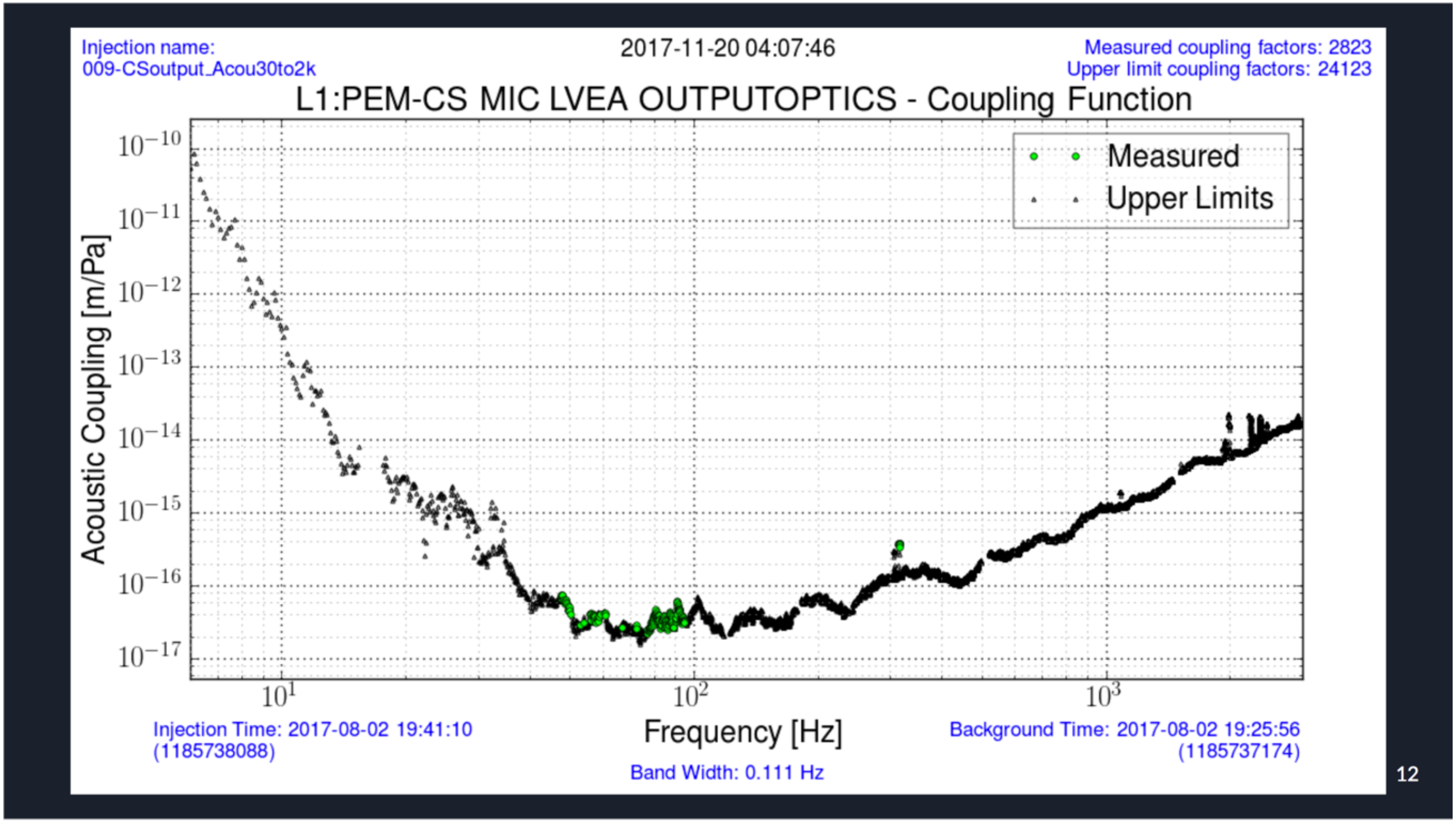
**Acoustic**



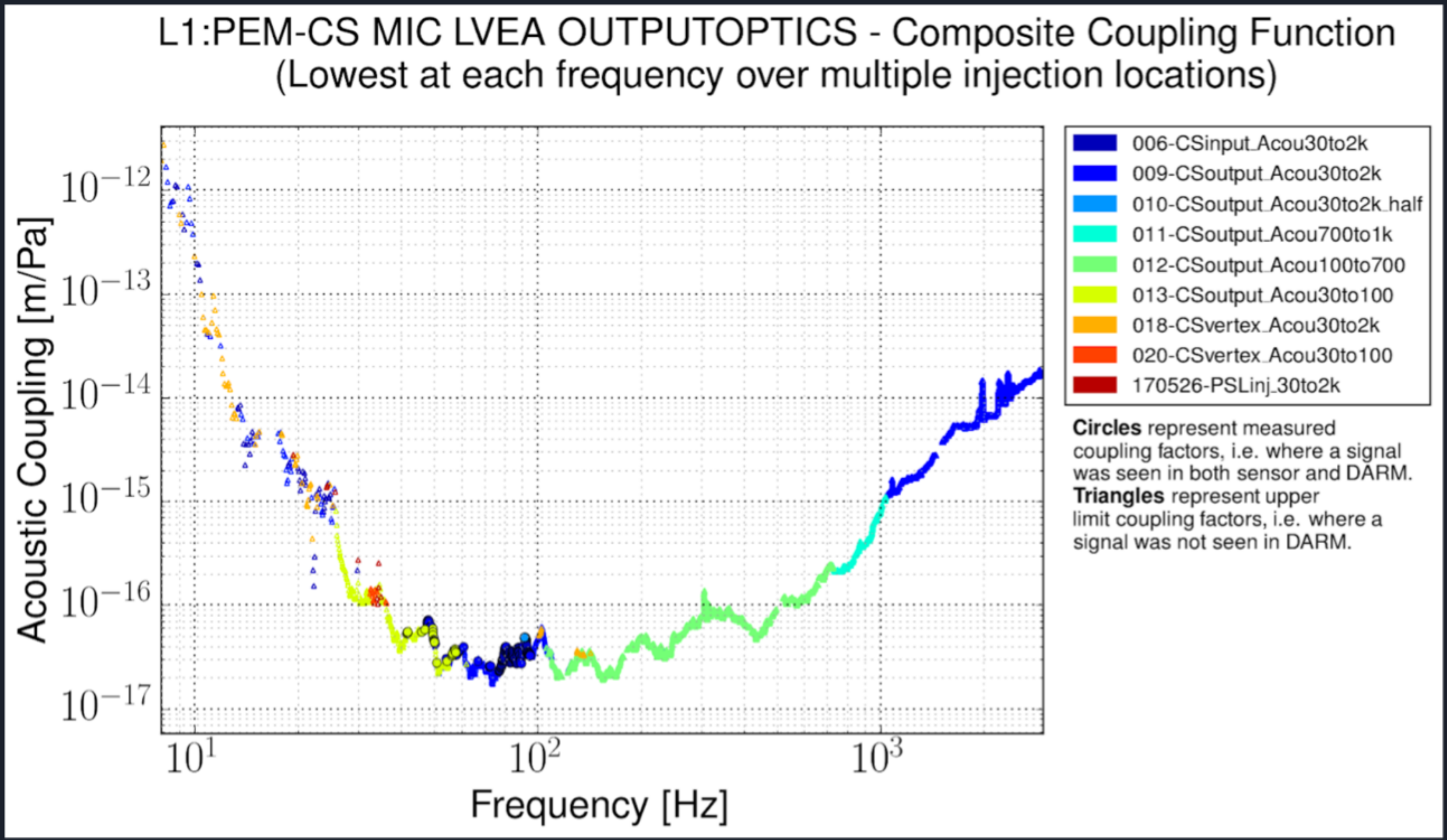

**Magnetic**



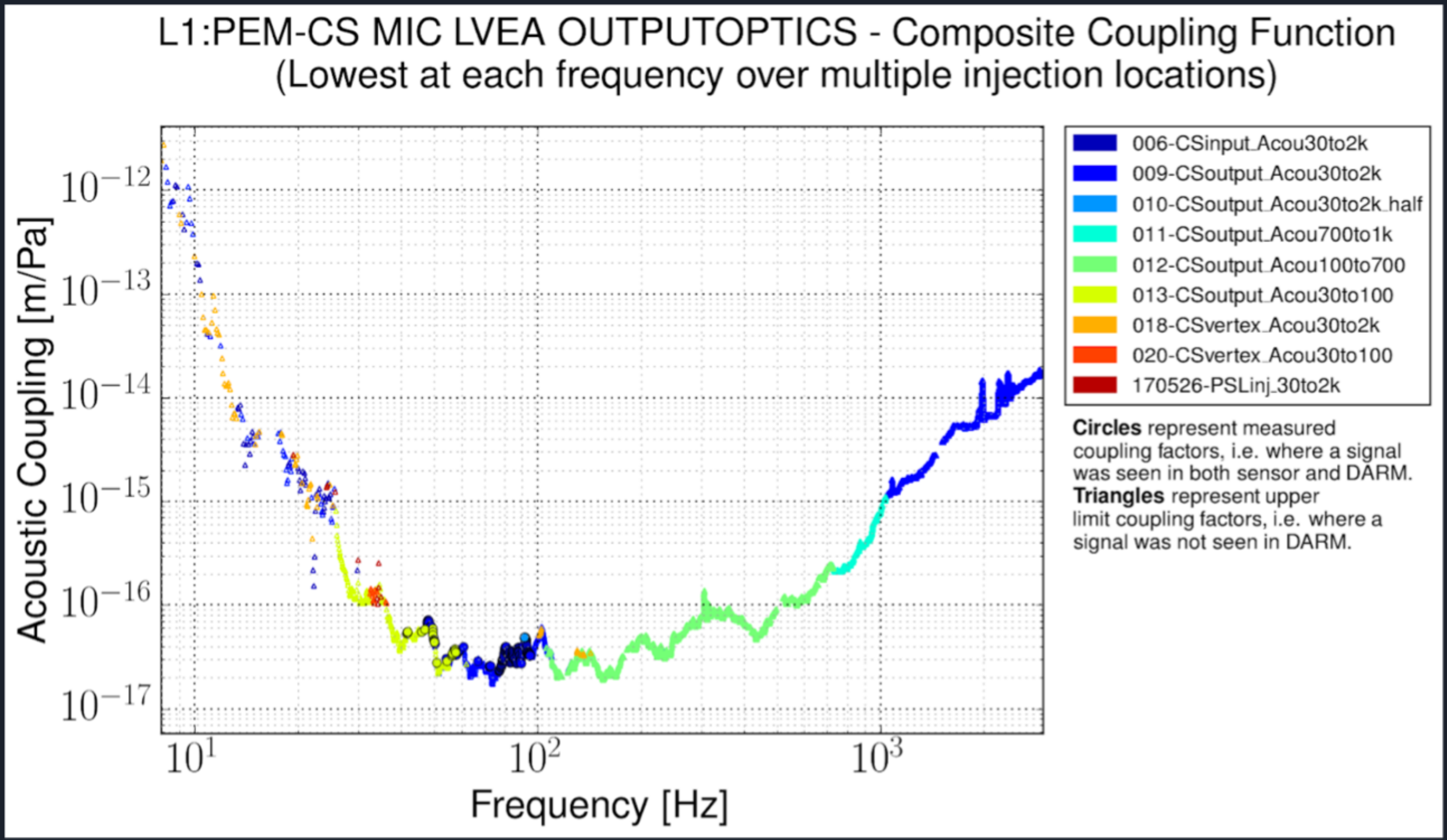
# Code first produces a coupling function (CF) for every relevant sensor for every injection



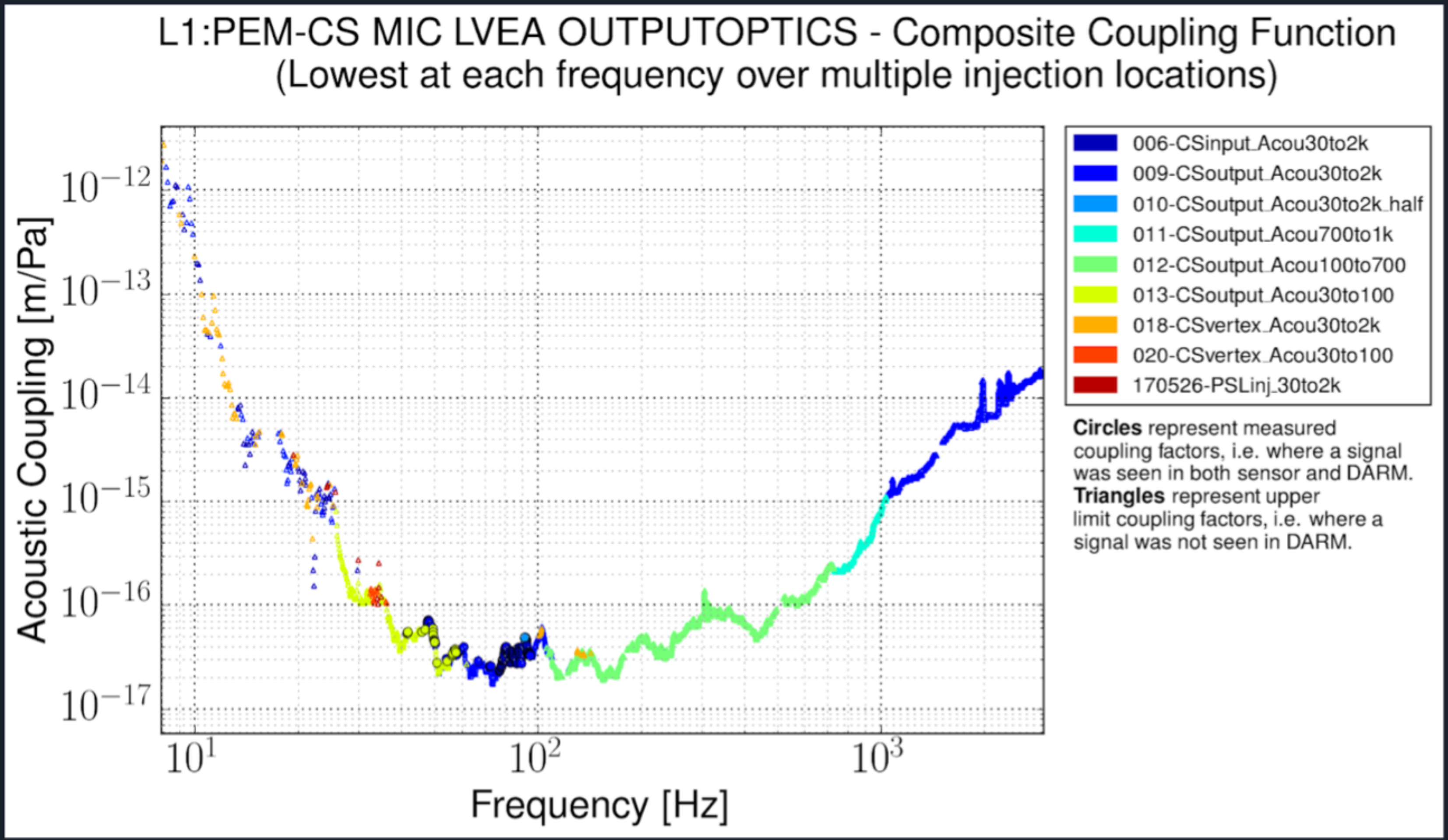
# These injection CFs are combined into a single CF for each channel by taking the lowest coupling factor at each frequency over multiple injection locations



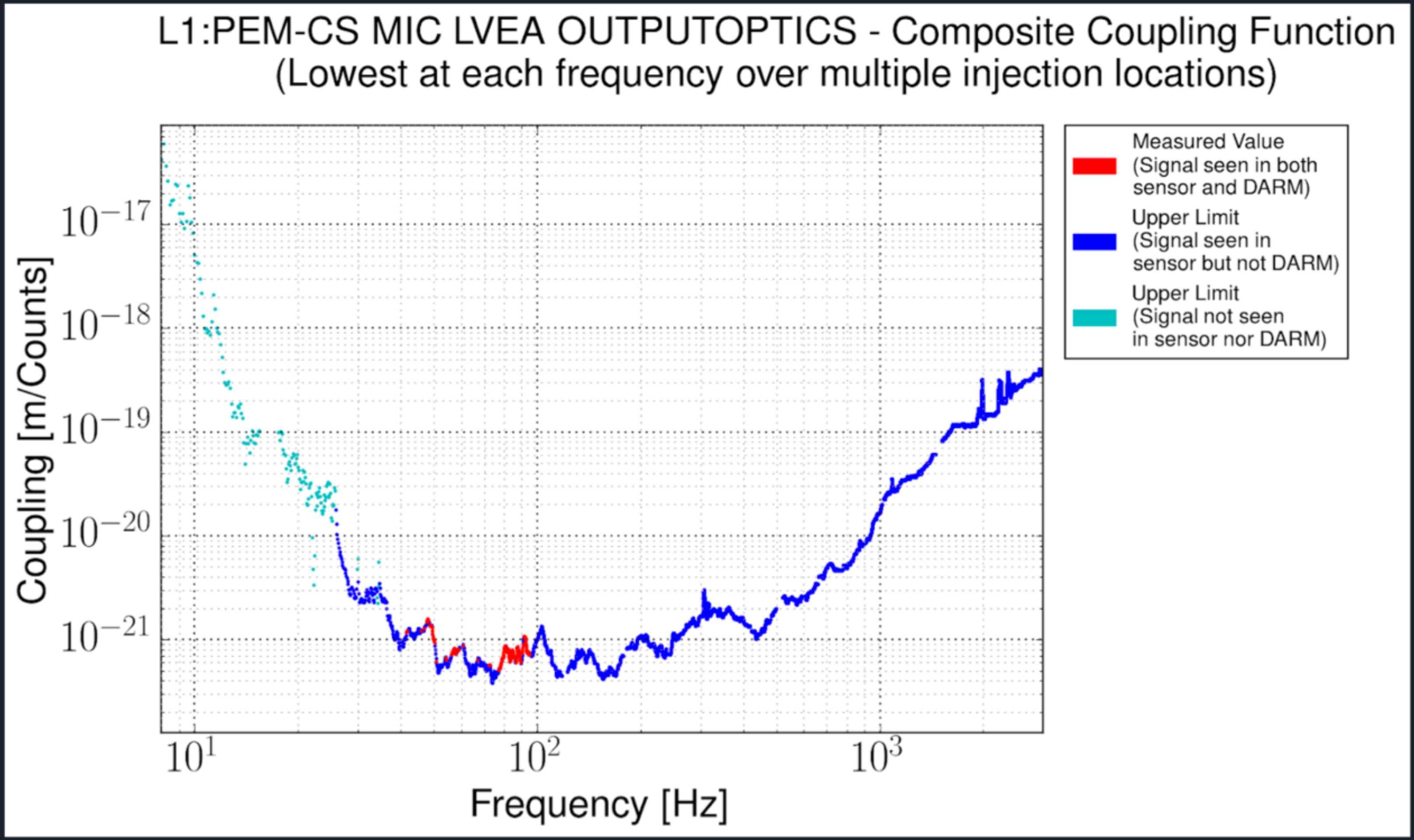
# We are currently developing more sophisticated combination methods than simply taking the lowest coupling factor



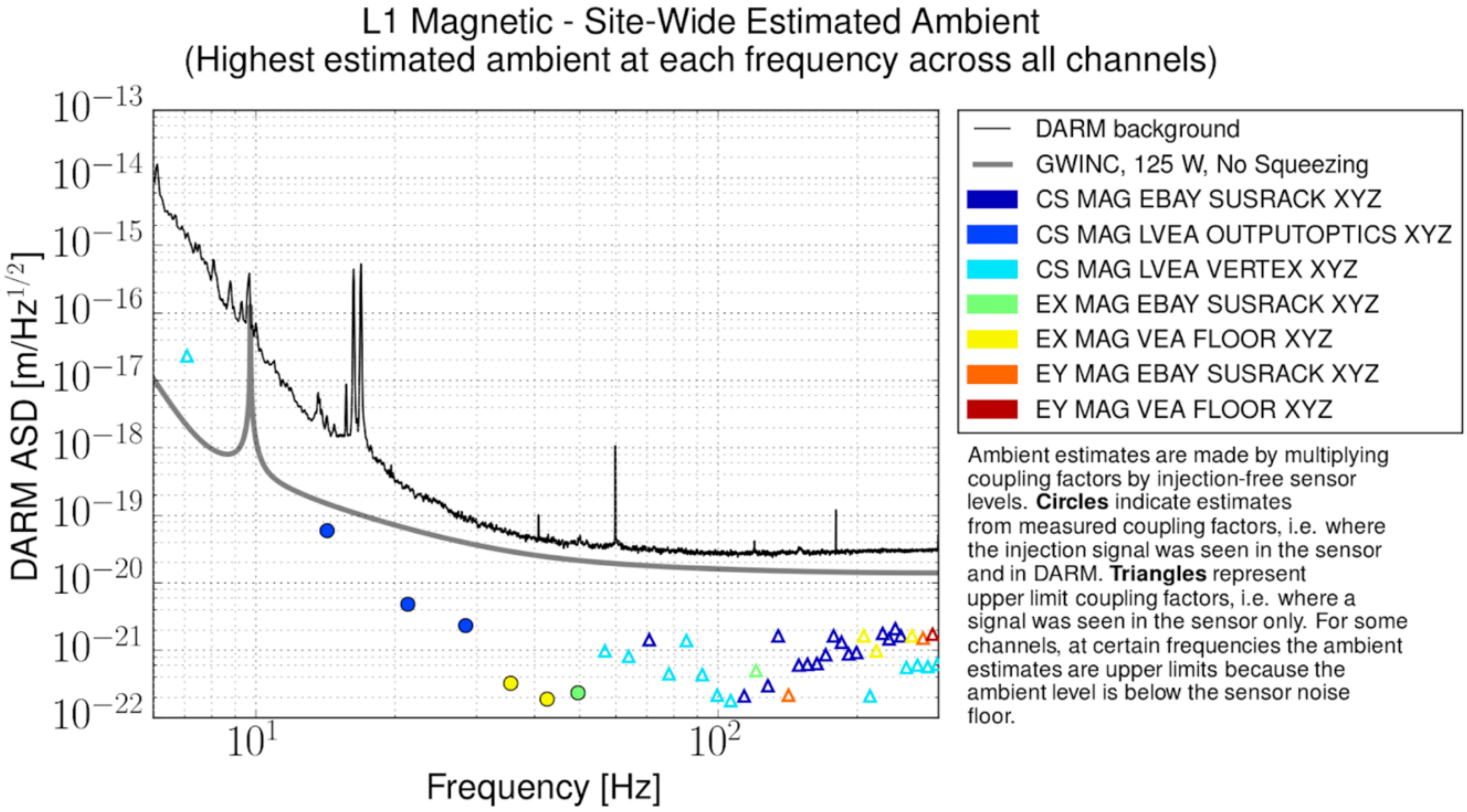
# Multiple versions of each coupling function: this version has physics units and injection locations



# Multiple versions of each coupling function: this version has m/count for easy/automated calculation

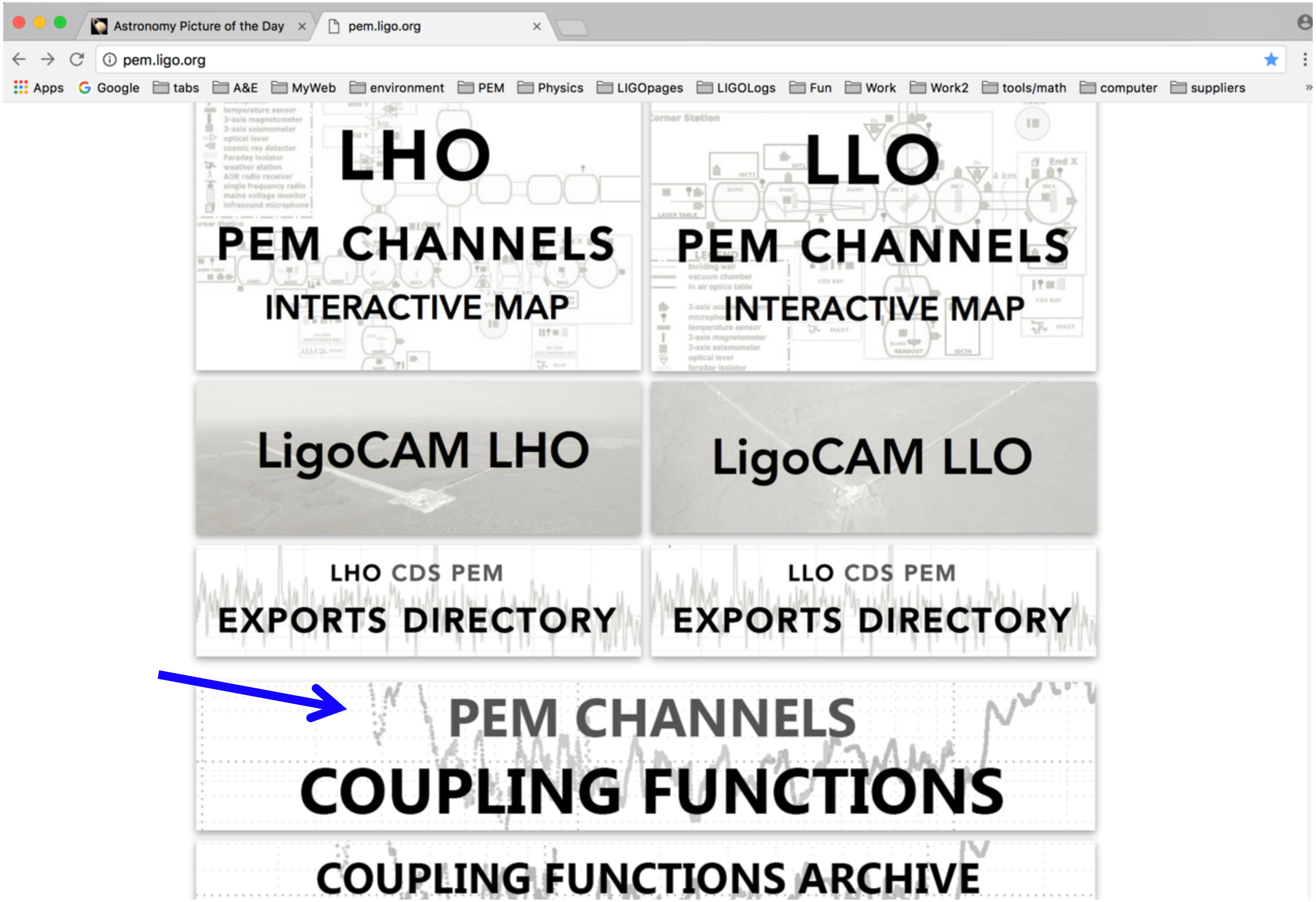


# And summary plots are made from all sensor channels showing highest coupling




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 only. For some channels, at certain frequencies the ambient estimates are upper limits because the ambient level is below the sensor noise floor.

# The data and plots are all located at PEM.LIGO.ORG



# PEM Coupling Functions

**All Channels**

Link

**By Location and Coupling Type**

| Interferometer | Station | Coupling Type |
|---|---|---|
| LHO | CS | Vibrational |
| LHO | CS | Magnetic |
| LHO | EX | Vibrational |
| LHO | EX | Magnetic |
| LHO | EY | Vibrational |
| LHO | EY | Magnetic |
| LLO | CS | Vibrational |
| LLO | CS | Magnetic |
| LLO | EX | Vibrational |
| LLO | EX | Magnetic |
| LLO | EY | Vibrational |
| LLO | EY | Magnetic |

**Documentation**

Analysis Procedure

**Site-Wide Summary Plots**

Link

# Count coupling functions for easy/automated estimation of DARM contribution

# PEM Coupling Functions

**All Channels**

Link

**By Location and Coupling Type**

| Interferometer | Station | Coupling Type |
|---|---|---|
| LHO | CS | Vibrational |
| LHO | CS | Magnetic |
| LHO | EX | Vibrational |
| LHO | EX | Magnetic |
| LHO | EY | Vibrational |
| LHO | EY | Magnetic |
| LLO | CS | Vibrational |
| LLO | CS | Magnetic |
| LLO | EX | Vibrational |
| LLO | EX | Magnetic |
| LLO | EY | Vibrational |
| LLO | EY | Magnetic |

**Documentation**

Analysis Procedure

**Site-Wide Summary Plots**

Link

# PEM Coupling Functions - All Channels (Current)

| Channel | Links |
|---|---|
| H1:IMC-WFS_A_DC_PIT_OUT | Data Plot |
| H1:IMC-WFS_A_DC_YAW_OUT | Data Plot |
| H1:PEM-CS_ACC_BEAMTUBE_MCTUBE_Y | Data Plot |
| H1:PEM-CS_ACC_BEAMTUBE_XMAN_Y | Data Plot |
| H1:PEM-CS_ACC_BEAMTUBE_YMAN_X | Data Plot |
| H1:PEM-CS_ACC_BSC1_ITMY_X | Data Plot |
| H1:PEM-CS_ACC_BSC1_ITMY_Y | Data Plot |
| H1:PEM-CS_ACC_BSC1_ITMY_Z | Data Plot |
| H1:PEM-CS_ACC_BSC2_BS_Y | Data Plot |
| H1:PEM-CS_ACC_BSC3_ITMX_X | Data Plot |
| H1:PEM-CS_ACC_BSC3_ITMX_Y | Data Plot |
| H1:PEM-CS_ACC_EBAY_FLOOR_Z | Data Plot |
| H1:PEM-CS_ACC_HAM2_PRM_Y | Data Plot |
| H1:PEM-CS_ACC_HAM2_PRM_Z | Data Plot |
| H1:PEM-CS_ACC_HAM3_PR2_Y | Data Plot |
| H1:PEM-CS_ACC_HAM4_SR2_X | Data Plot |
| H1:PEM-CS_ACC_HAM5_SRM_X | Data Plot |
| H1:PEM-CS_ACC_HAM6_OMC_X | Data Plot |
| H1:PEM-CS_ACC_HAM6_OMC_Z | Data Plot |
| H1:PEM-CS_ACC_IOT1_IMC_X | Data Plot |
| H1:PEM-CS_ACC_IOT1_IMC_Y | Data Plot |
| H1:PEM-CS_ACC_IOT1_IMC_Z | Data Plot |
| H1:PEM-CS_ACC_ISCT1_REFL_Y | Data Plot |
| H1:PEM-CS_ACC_OPLEV_ITMX_Y | Data Plot |
| H1:PEM-CS_ACC_OPLEV_ITMY_X | Data Plot |
| H1:PEM-CS_ACC_PSL_PERISCOPE_X | Data Plot |

```
frequency,factor,factor_counts,flag,ambient,darm
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8.3333333333,7.18644119284e-08,2.6212994202e-17,Thresholds not met,1.013490683e-16,1.39229022617e-16
8.4444444444,8.96042633371e-08,3.18292768212e-17,Thresholds not met,1.25179183537e-16,1.49891866622e-16
8.5555555556,8.51281184554e-08,2.9458923072e-17,Thresholds not met,1.03339334538e-16,1.36039873886e-16
8.6666666667,8.61525089417e-08,2.90538711603e-17,Thresholds not met,9.8555527441e-17,1.46039671224e-16
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9.2222222222,2.39644250612e-07,7.13733549546e-17,Thresholds not met,9.54080903854e-17,1.32242825787e-16
9.3333333333,1.76046826124e-07,5.11911528044e-17,Thresholds not met,8.89108513149e-17,1.5527944597e-16
9.4444444444,2.0551091961e-07,5.83609473955e-17,Thresholds not met,1.57349127193e-16,1.81772524653e-16
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9.6666666667,4.30900519342e-07,1.16805634919e-16,Thresholds not met,2.07707016451e-16,4.00008375878e-16
9.7777777778,1.38619122419e-07,3.67267994021e-17,Thresholds not met,5.92638421443e-17,8.71679435444e-16
9.8888888889,2.53427826736e-07,6.56446849261e-17,Thresholds not met,1.186717048e-16,8.45403219791e-16
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10.2222222222,1.95661704539e-07,4.74302550592e-17,Thresholds not met,3.64887789728e-17,9.8663305546e-17
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10.5555555556,1.42815754003e-07,3.24678991775e-17,Thresholds not met,1.65053663273e-17,4.33538927005e-17
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11.1111111111,1.10570516532e-07,2.26863496122e-17,Thresholds not met,9.88655784859e-18,2.31771470704e-17
11.2222222222,1.31446182726e-07,2.64381165656e-17,Thresholds not met,1.25092124583e-17,2.17412618783e-17
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11.7777777778,9.74813184664e-08,1.78006124994e-17,Thresholds not met,9.71838388977e-18,1.80231584755e-17
11.8888888889,6.11079694286e-08,1.09510454011e-17,Thresholds not met,7.00047874551e-18,1.61834361707e-17
```
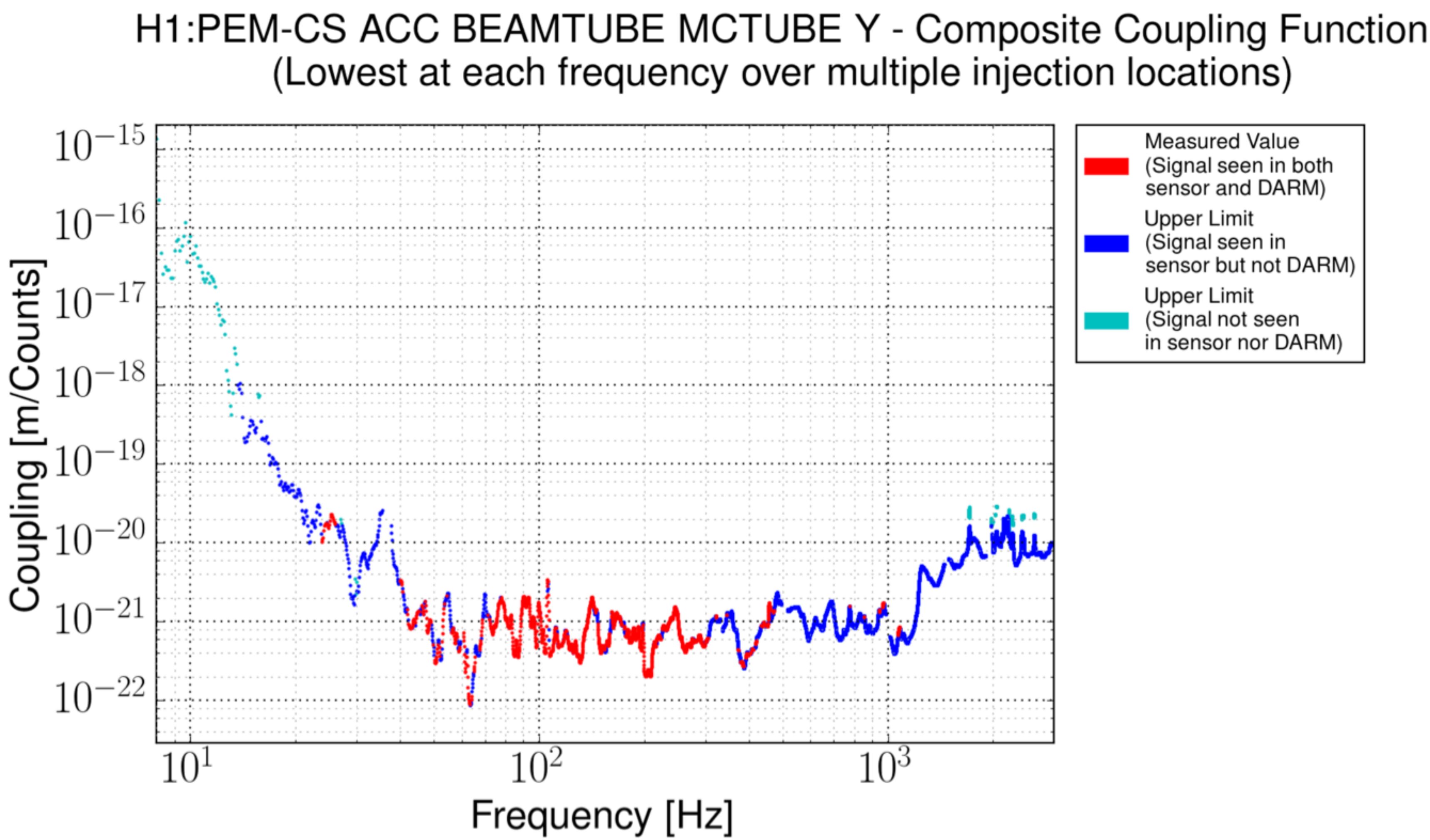

# PEM Coupling Functions - All Channels (Current)

| Channel | Links |
|---|---|
| H1:IMC-WFS_A_DC_PIT_OUT | Data Plot |
| H1:IMC-WFS_A_DC_YAW_OUT | Data Plot |
| H1:PEM-CS_ACC_BEAMTUBE_MCTUBE_Y | Data Plot |
| H1:PEM-CS_ACC_BEAMTUBE_XMAN_Y | Data Plot |
| H1:PEM-CS_ACC_BEAMTUBE_YMAN_X | Data Plot |
| H1:PEM-CS_ACC_BSC1_ITMY_X | Data Plot |
| H1:PEM-CS_ACC_BSC1_ITMY_Y | Data Plot |
| H1:PEM-CS_ACC_BSC1_ITMY_Z | Data Plot |
| H1:PEM-CS_ACC_BSC2_BS_Y | Data Plot |
| H1:PEM-CS_ACC_BSC3_ITMX_X | Data Plot |
| H1:PEM-CS_ACC_BSC3_ITMX_Y | Data Plot |
| H1:PEM-CS_ACC_EBAY_FLOOR_Z | Data Plot |
| H1:PEM-CS_ACC_HAM2_PRM_Y | Data Plot |
| H1:PEM-CS_ACC_HAM2_PRM_Z | Data Plot |
| H1:PEM-CS_ACC_HAM3_PR2_Y | Data Plot |
| H1:PEM-CS_ACC_HAM4_SR2_X | Data Plot |
| H1:PEM-CS_ACC_HAM5_SRM_X | Data Plot |
| H1:PEM-CS_ACC_HAM6_OMC_X | Data Plot |
| H1:PEM-CS_ACC_HAM6_OMC_Z | Data Plot |
| H1:PEM-CS_ACC_IOT1_IMC_X | Data Plot |
| H1:PEM-CS_ACC_IOT1_IMC_Y | Data Plot |
| H1:PEM-CS_ACC_IOT1_IMC_Z | Data Plot |
| H1:PEM-CS_ACC_ISCT1_REFL_Y | Data Plot |
| H1:PEM-CS_ACC_OPLEV_ITMX_Y | Data Plot |
| H1:PEM-CS_ACC_OPLEV_ITMY_X | Data Plot |
| H1:PEM-CS_ACC_PSL_PERISCOPE_X | Data Plot |



H1:PEM-CS ACC BEAMTUBE MCTUBE Y - Composite Coupling Function
(Lowest at each frequency over multiple injection locations)
Coupling [m/Counts]
$10^{-15}$
$10^{-16}$
$10^{-17}$
$10^{-18}$
$10^{-19}$
$10^{-20}$
$10^{-21}$
$10^{-22}$
$10^{1}$
$10^{2}$
$10^{3}$
Frequency [Hz]
Measured Value (Signal seen in both sensor and DARM)
Upper Limit (Signal seen in sensor but not DARM)
Upper Limit (Signal not seen in sensor nor DARM)

# Summary plots

# PEM Coupling Functions

**All Channels**

Link

**By Location and Coupling Type**

| Interferometer | Station | Coupling Type |
|---|---|---|
| LHO | CS | Vibrational |
| LHO | CS | Magnetic |
| LHO | EX | Vibrational |
| LHO | EX | Magnetic |
| LHO | EY | Vibrational |
| LHO | EY | Magnetic |
| LLO | CS | Vibrational |
| LLO | CS | Magnetic |
| LLO | EX | Vibrational |
| LLO | EX | Magnetic |
| LLO | EY | Vibrational |
| LLO | EY | Magnetic |

**Documentation**

Analysis Procedure

**Site-Wide Summary Plots**

Link

# Summary plots

## PEM Coupling Functions - Site-Wide Summary Plots

**LLO Magnetic**

Estimated Ambient

Coupling Function

**LLO Vibrational**

Estimated Ambient

Coupling Function (ACC)

Coupling Function (MIC)

**LHO Magnetic**

Estimated Ambient

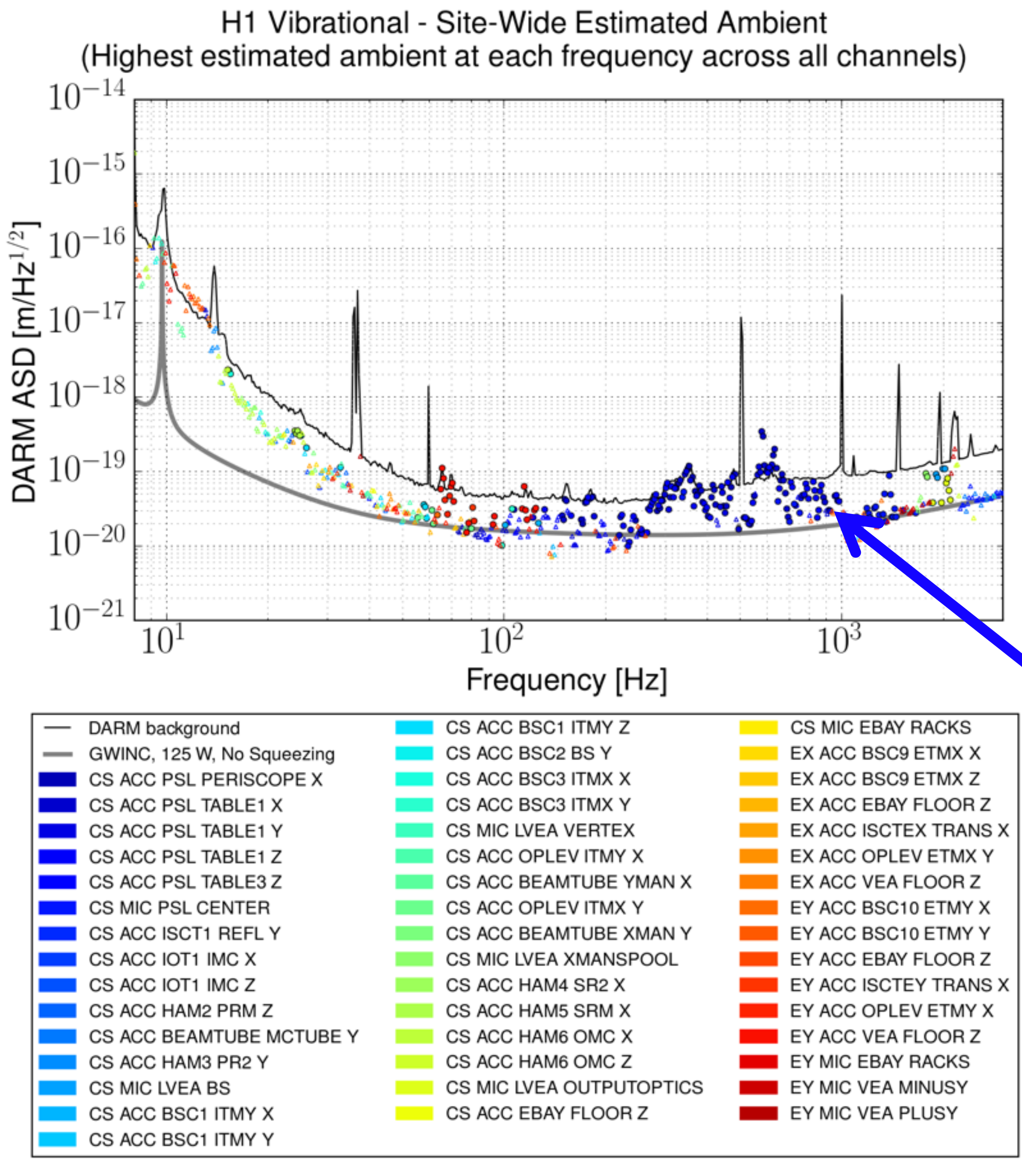
Coupling Function

**LHO Vibrational**

Estimated Ambient

Coupling Function (ACC)

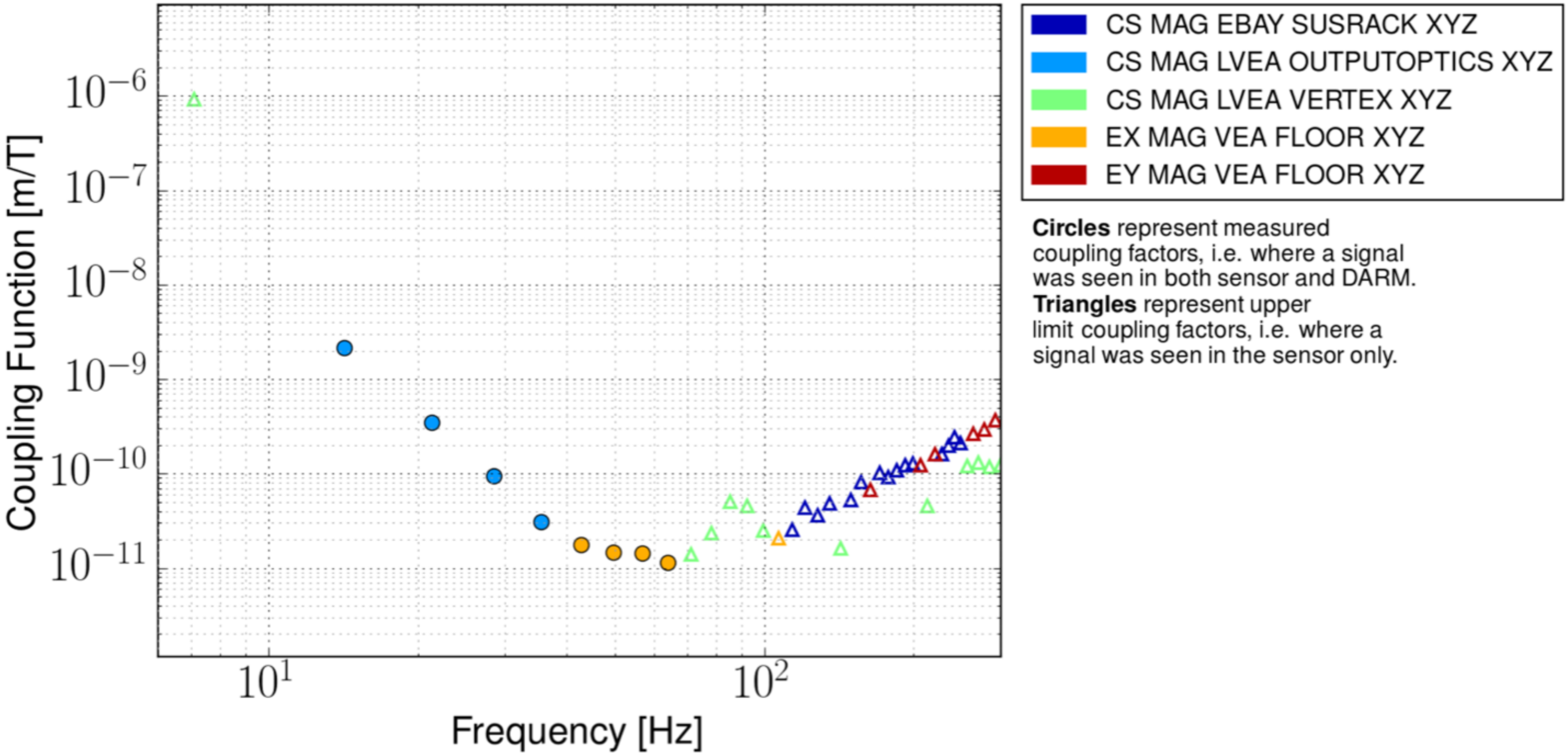
Coupling Function (MIC)




Hanford input beam jitter coupling

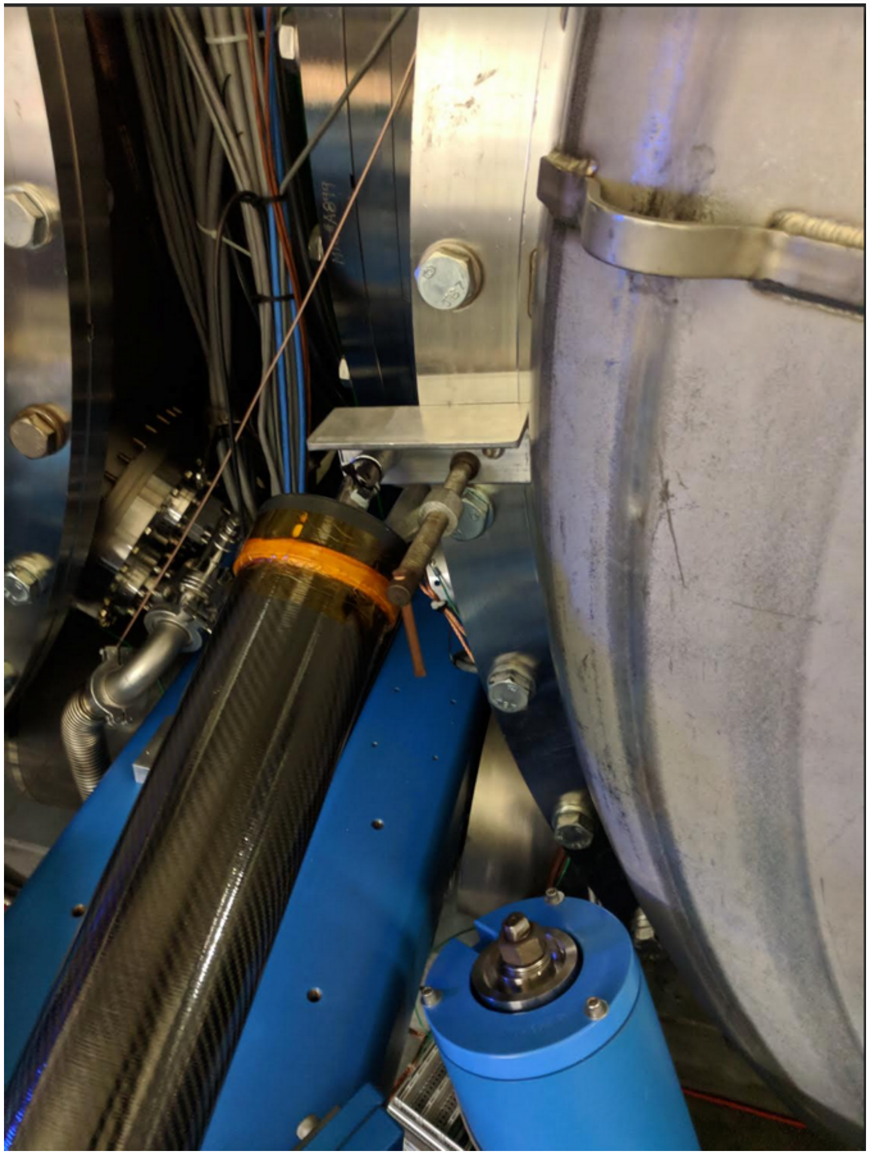
Ambient estimates are made by multiplying coupling factors by injection-free sensor levels. **Circles** indicate estimates from measured coupling factors, i.e. where the injection signal was seen in the sensor and in DARM. **Triangles** represent upper limit coupling factors, i.e. where a signal was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

L1 Magnetic - Site-Wide Coupling Function
(Highest coupling factor at each frequency across all channels)




**Circles** represent measured coupling factors, i.e. where a signal was seen in both sensor and DARM.
**Triangles** represent upper limit coupling factors, i.e. where a signal was seen in the sensor only.

# B. New low-f shaking system at LLO, with stiff connecting rod

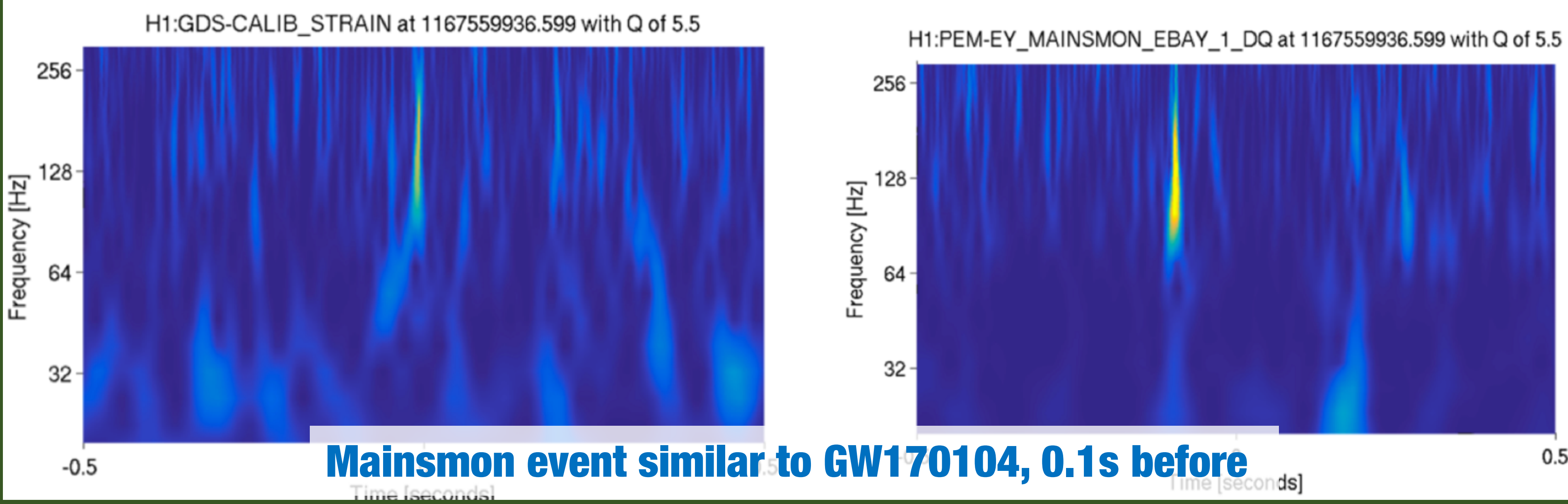


# III. Plans for BBH vetting in O3

**A. LigoCAM-based PEM coverage assessment by expert**

**B. Expert review of DetChar-supplied links to triggered channel spectrograms using PEM configuration files.**

**C. Rarely, coupling calculations for any PEM TF paths that are similar to inspiral, using coupling functions on PEM.LIGO.ORG**




**Mainsmon event similar to GW170104, 0.1s before**

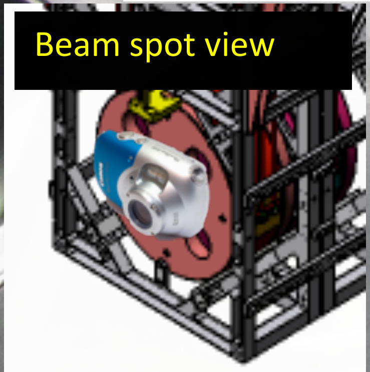
# Most important PEM-related commissioning for O3

A. Beam jitter investigation/minimization especially at LHO

B. Scattering investigations - feedback to Stray Light Control project

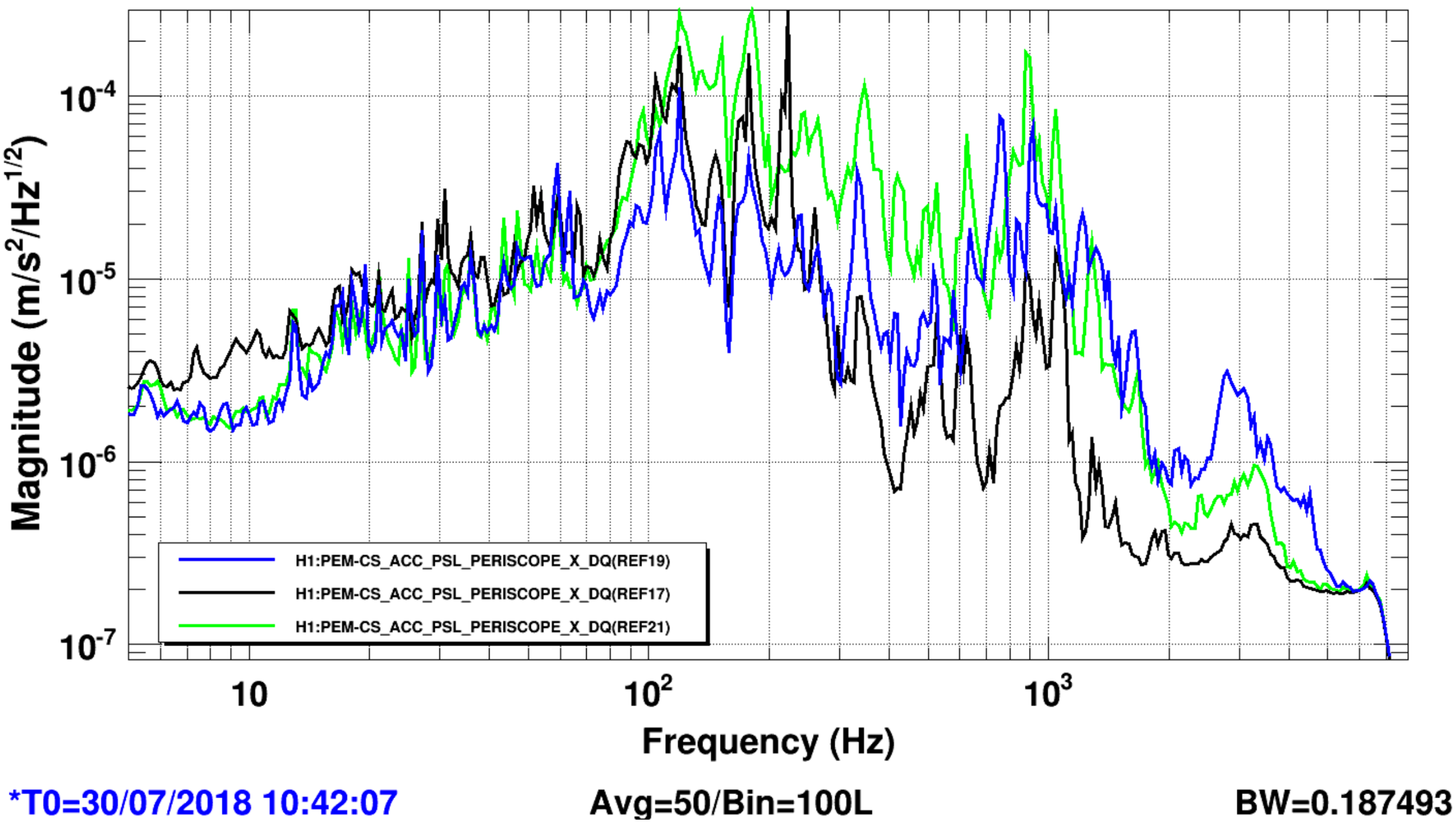
C. New squeezer couplings

D. Blip-glitches, other glitches and lines



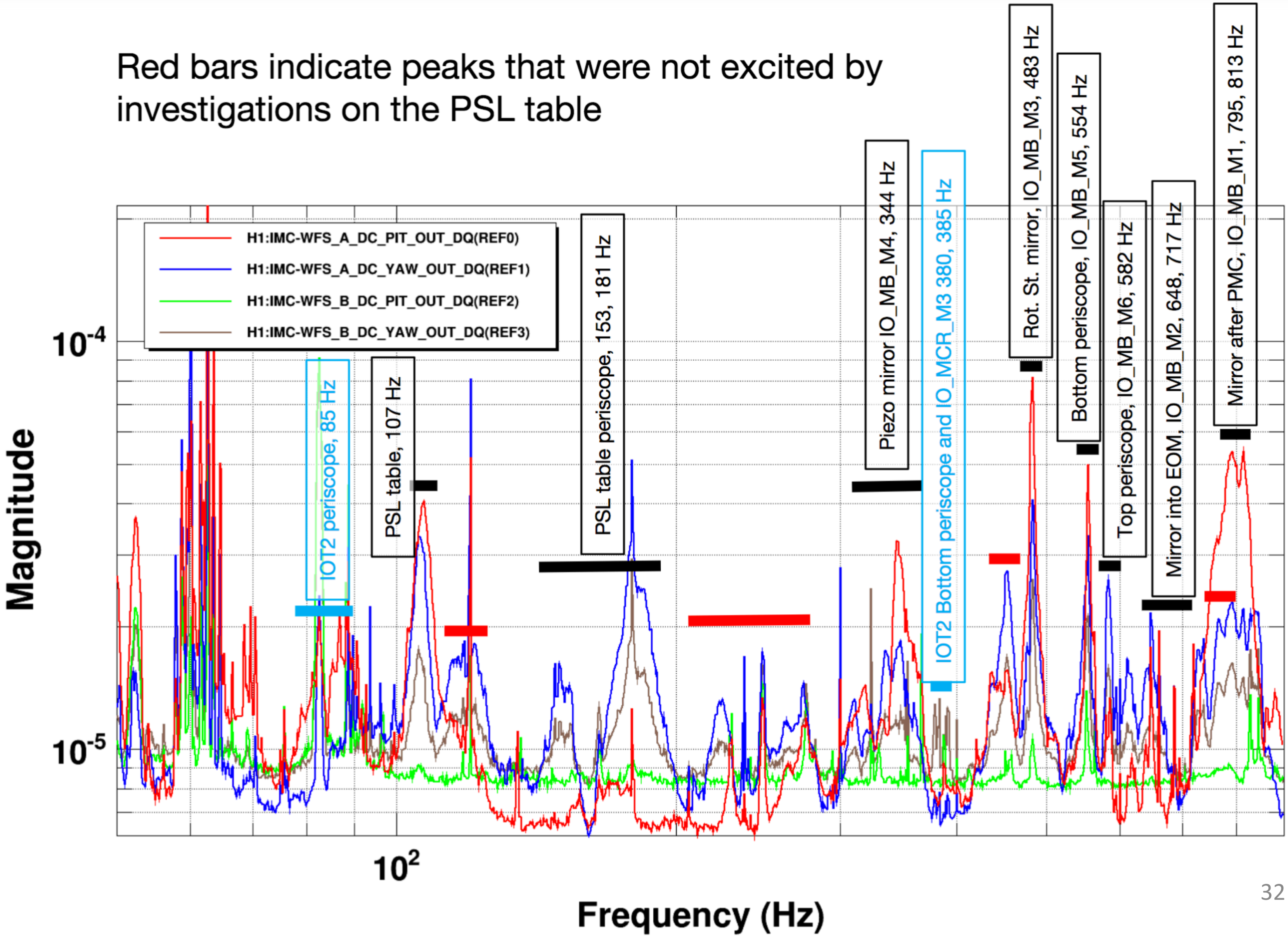
# A. Status of LHO PSL table motion

**BLUE: July 30, 2018, BLACK: no water flow Feb. 12, GREEN: Aug. 17, 2017**



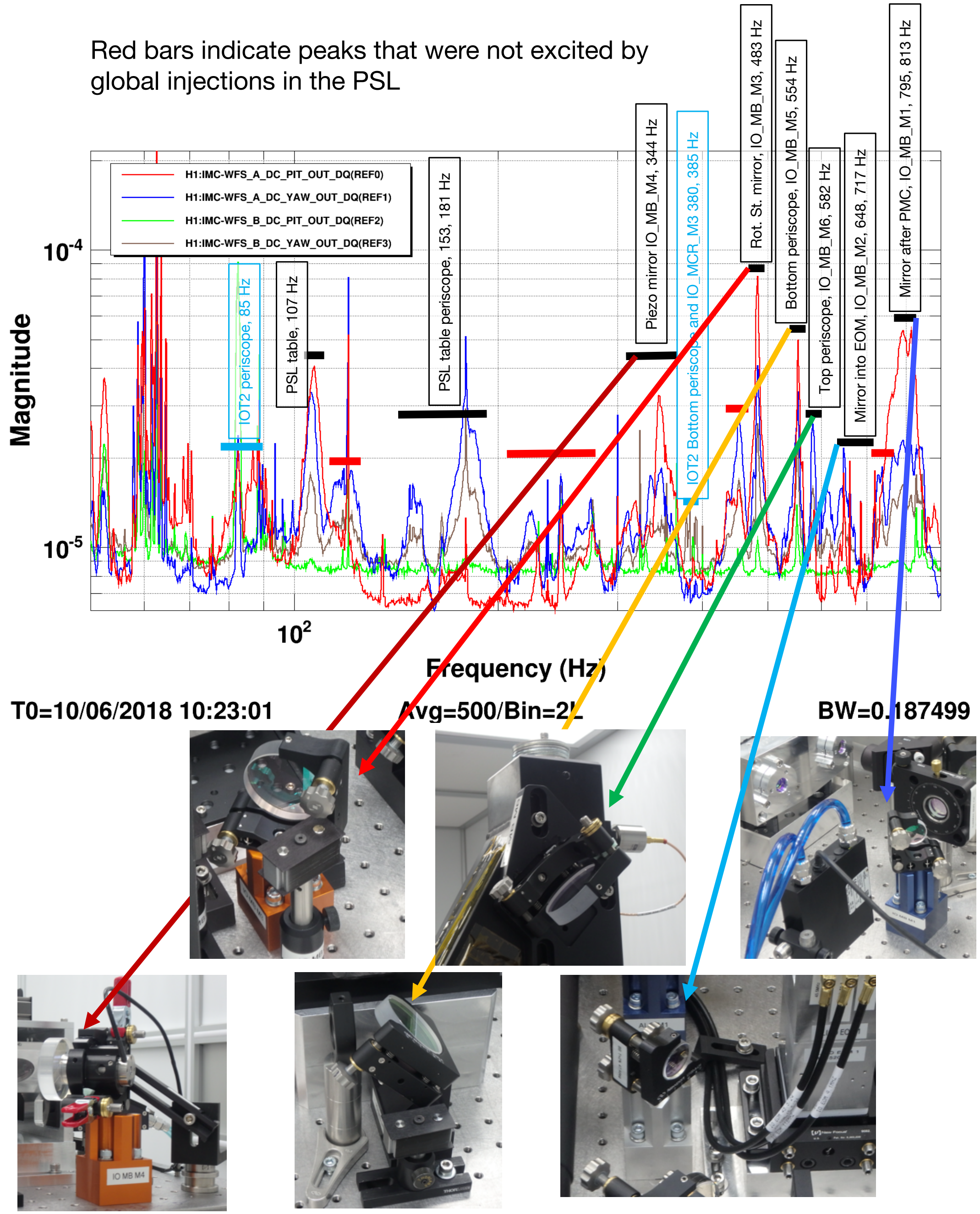
# A. Identification of peaks in LHO jitter spectrum

Red bars indicate peaks that were not excited by investigations on the PSL table



# Identification of peaks in the IMC WFS DC spectra

Red bars indicate peaks that were not excited by global injections in the PSL

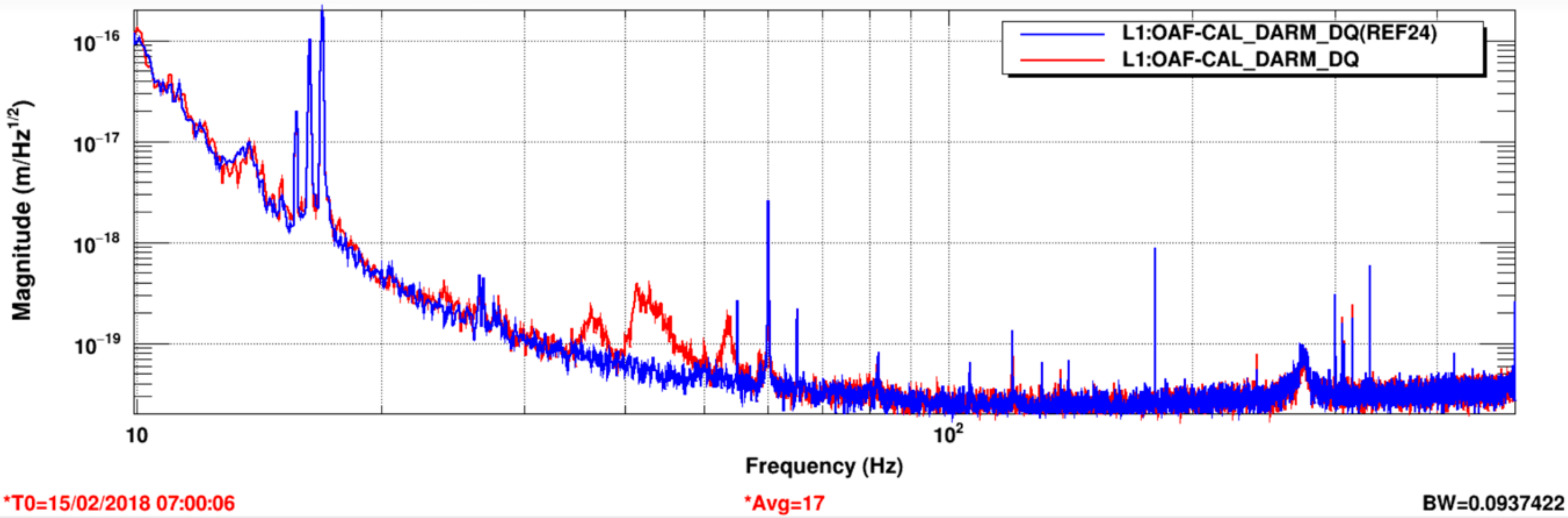


# B. Scattering investigations and feedback to SLiC

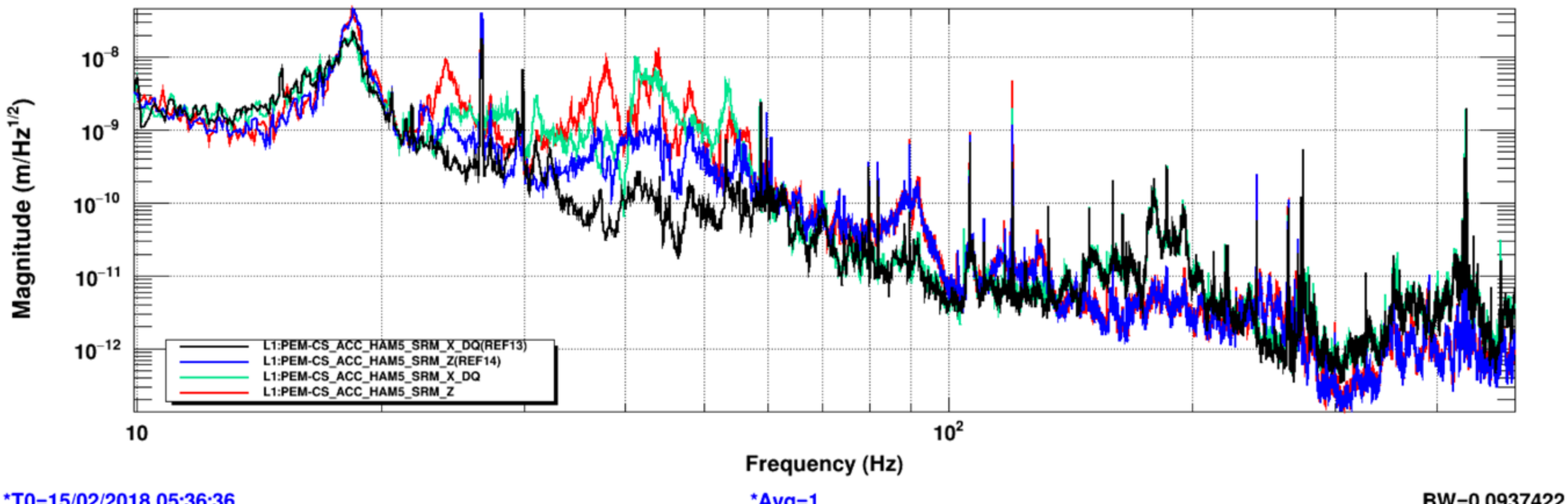
1. Low-f shaker coupling measurements LLO/LHO
2. Some mitigation photos
3. Beam spot photos at LHO
4. Glint ranking for wide angle scattering at LHO

# 1. Factor of ~10 increase in LLO HAM5,6 motion in 40 Hz region produces ~10 increase in DARM

DARM

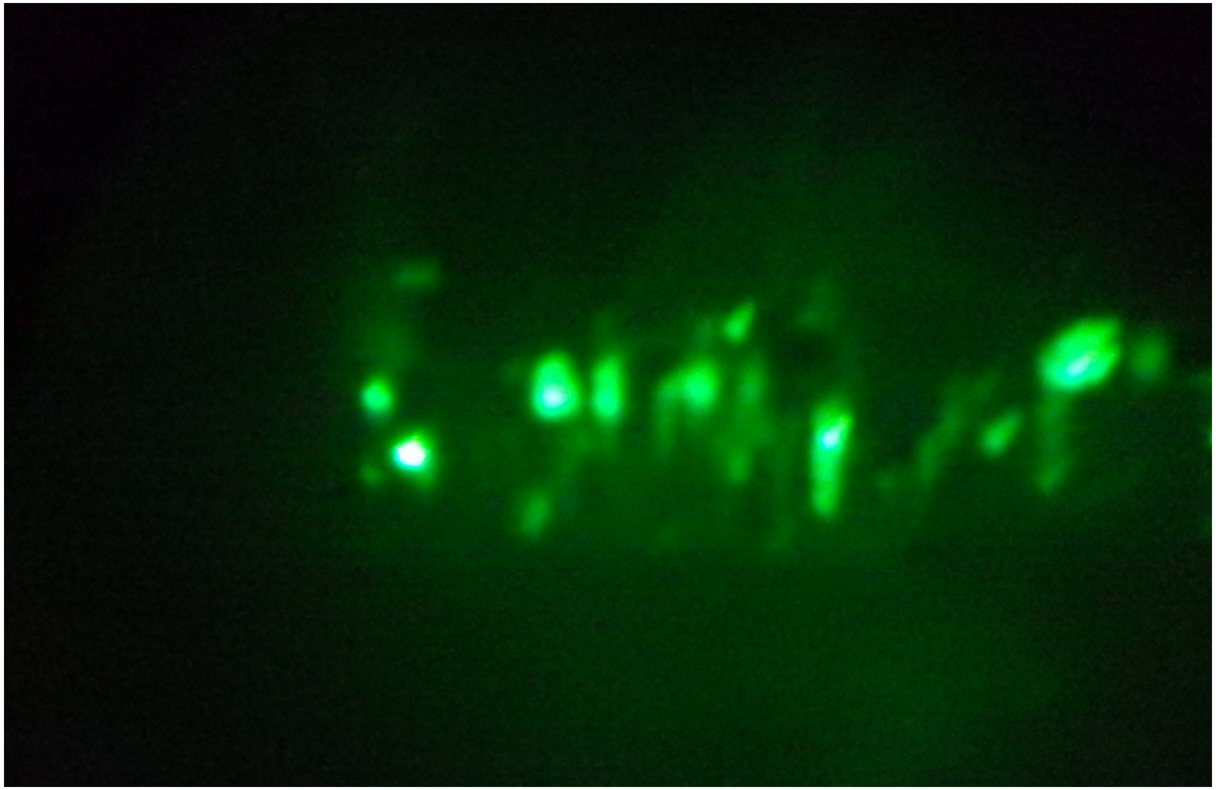



some sensors



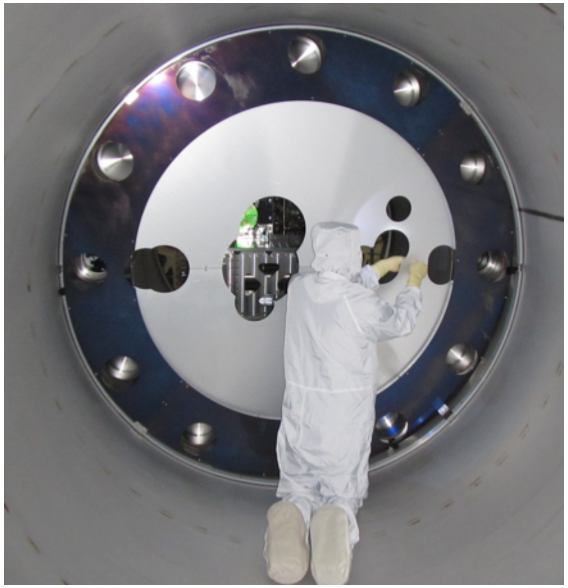
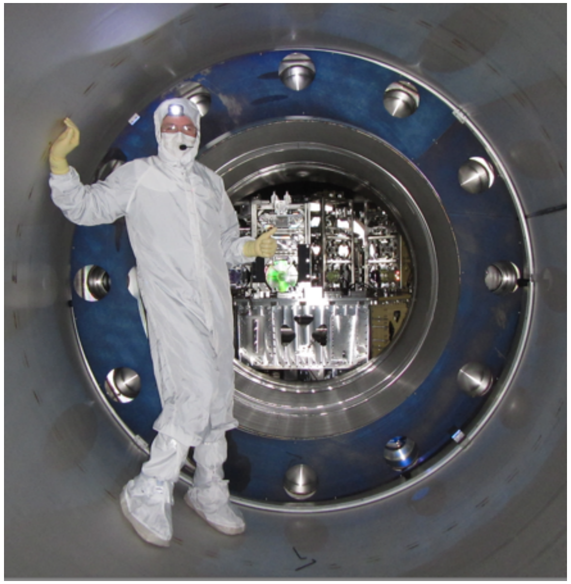
# 1. Possible scattering path: OFI to vacuum enclosure and back

1) Shaking produces DARM noise at vacuum enclosure resonances
2) Moving OFI, using new actuators, strong scattering, modulates chamber peak
3) OFI is greatest source of scattered light visible at view ports.

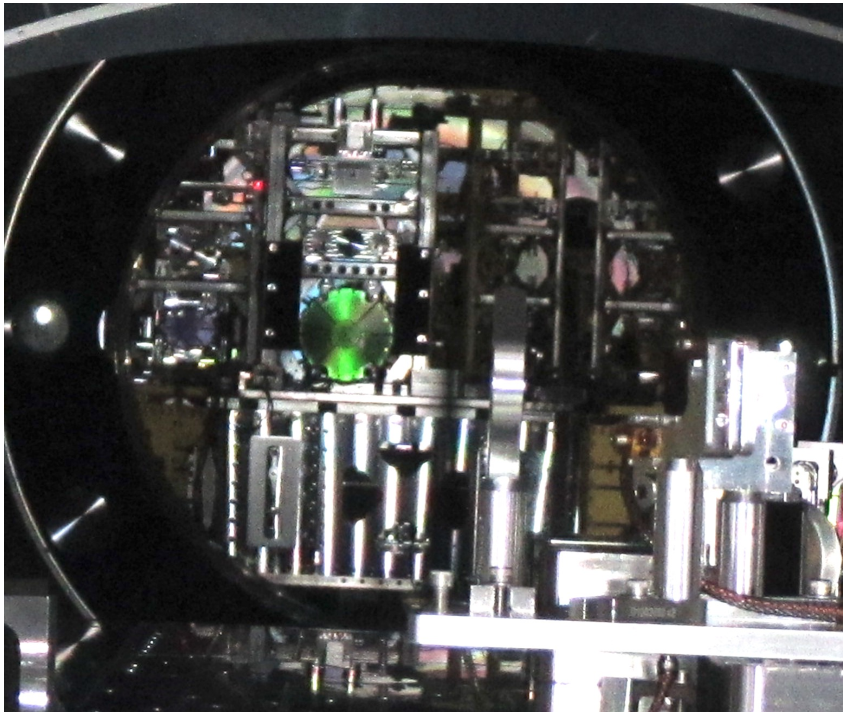


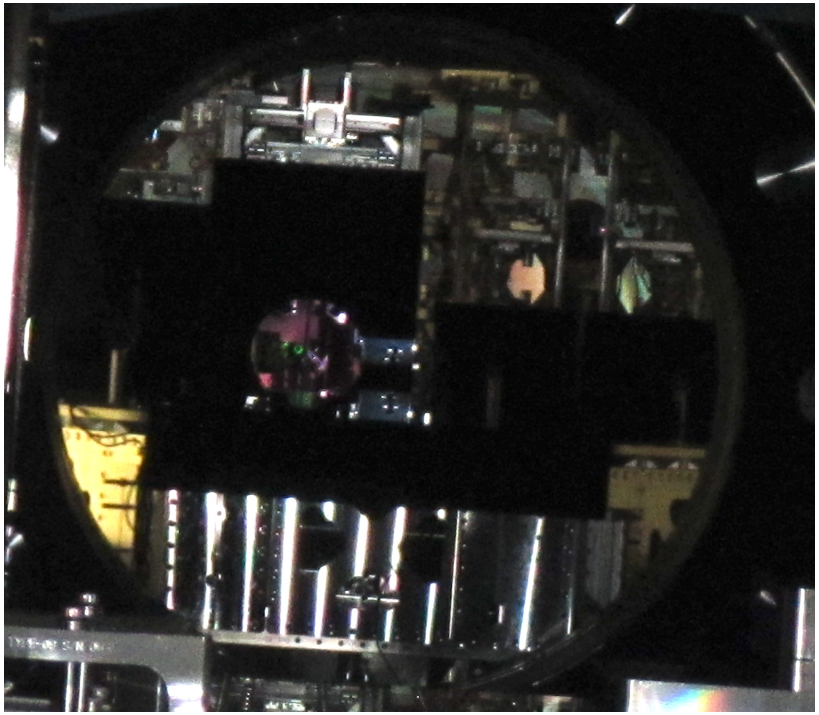
**Block paths from OFI to vacuum enclosure?**

# 2. Removal of Swiss-cheese baffle

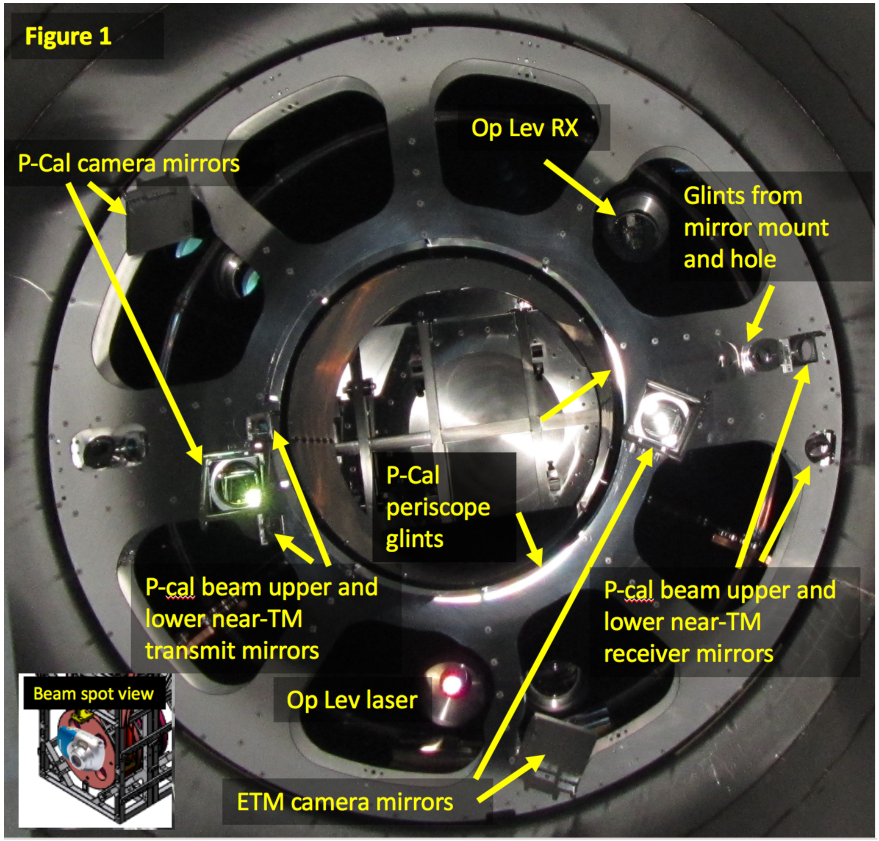
# 2. Before and after baffling at HAM2

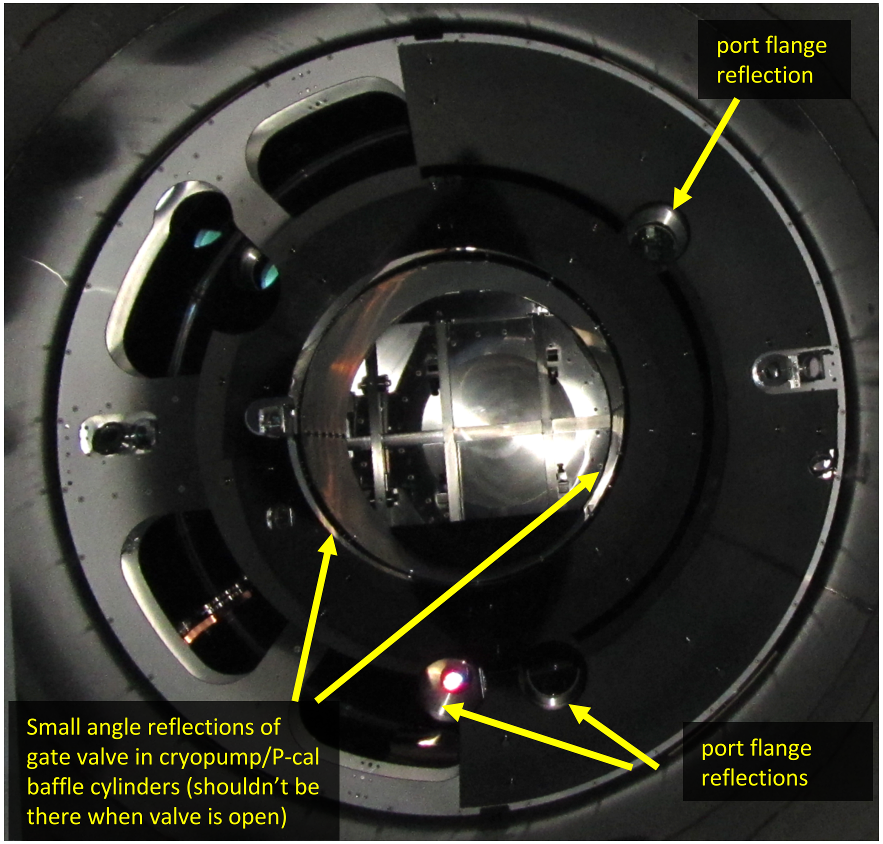




# 2. P-Cal periscope baffling

**Figure 1.** View from ITMY beam-spot before and after stray light upgrade of P-cal periscope



# Raven pecks likely couple at P-Cal periscope

## Ravens peck at ice accumulating on nitrogen discharge line from cryopump

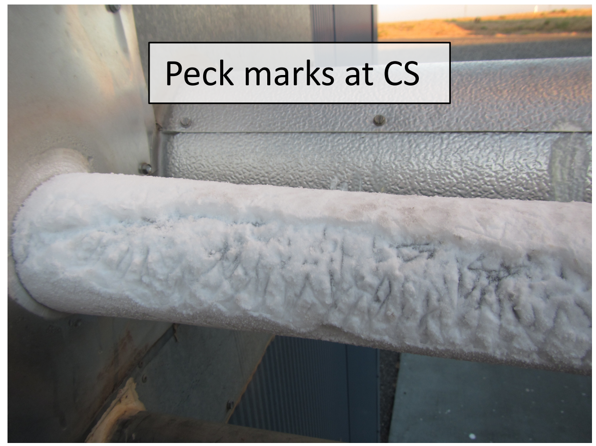
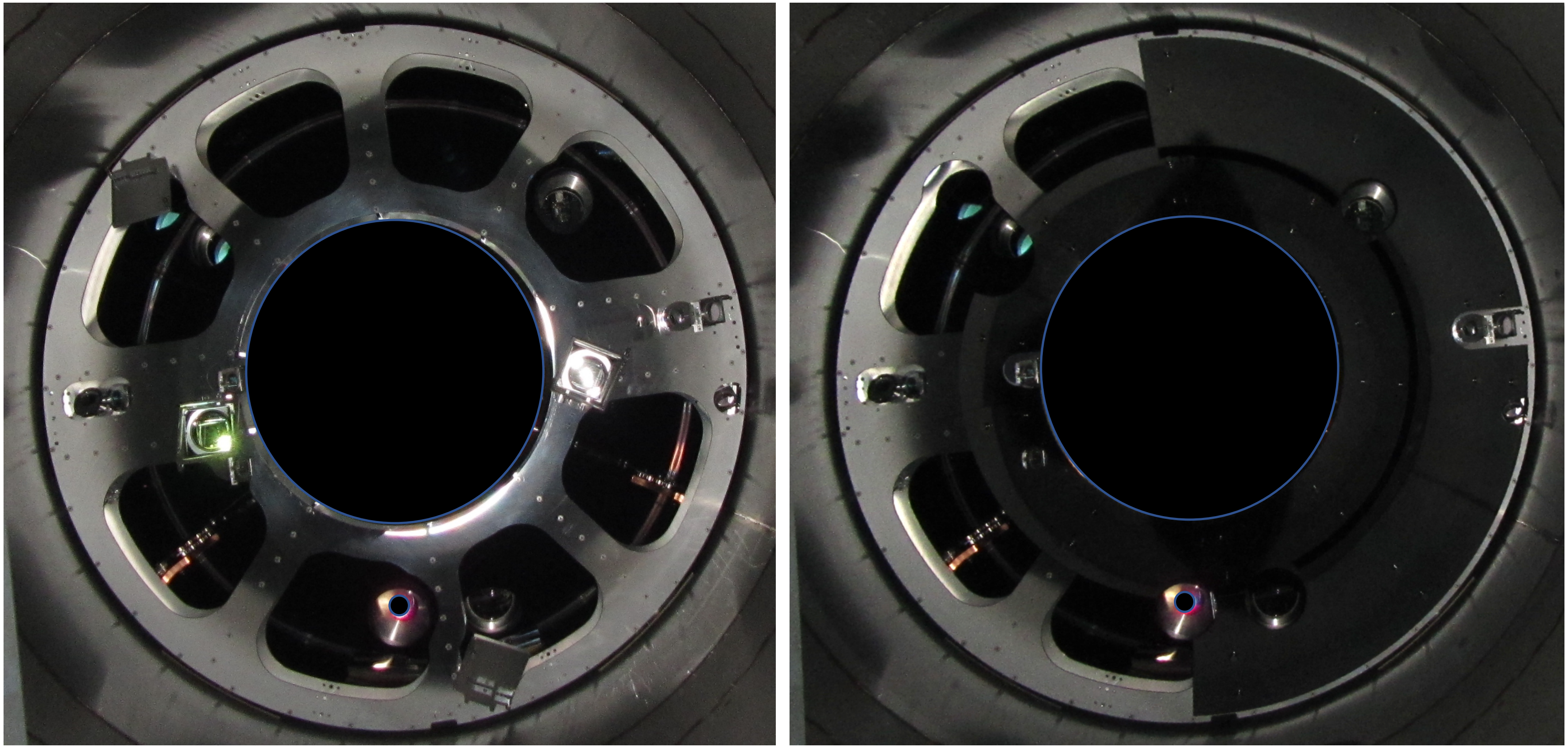
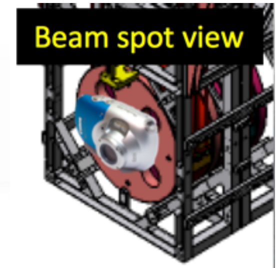






**Figure 3.** View from ETMY beam spot, before and after stray light upgrade, with optical lever beam and reflections from gate valve (at center), blacked out



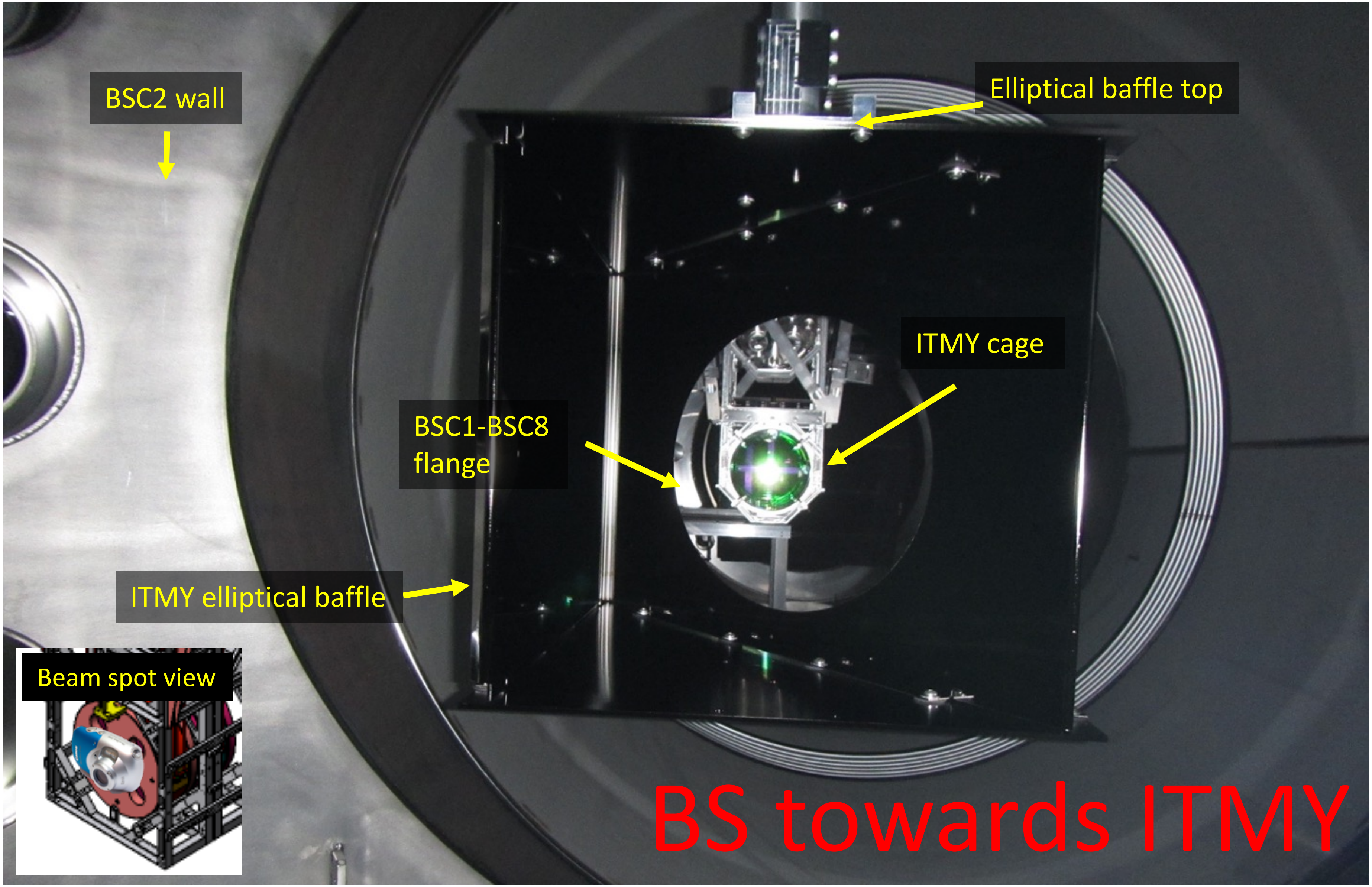
# 3. Views from beam spots at LHO





https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=41142

# 4. Assessing the importance of glints in beam-spot view photographs

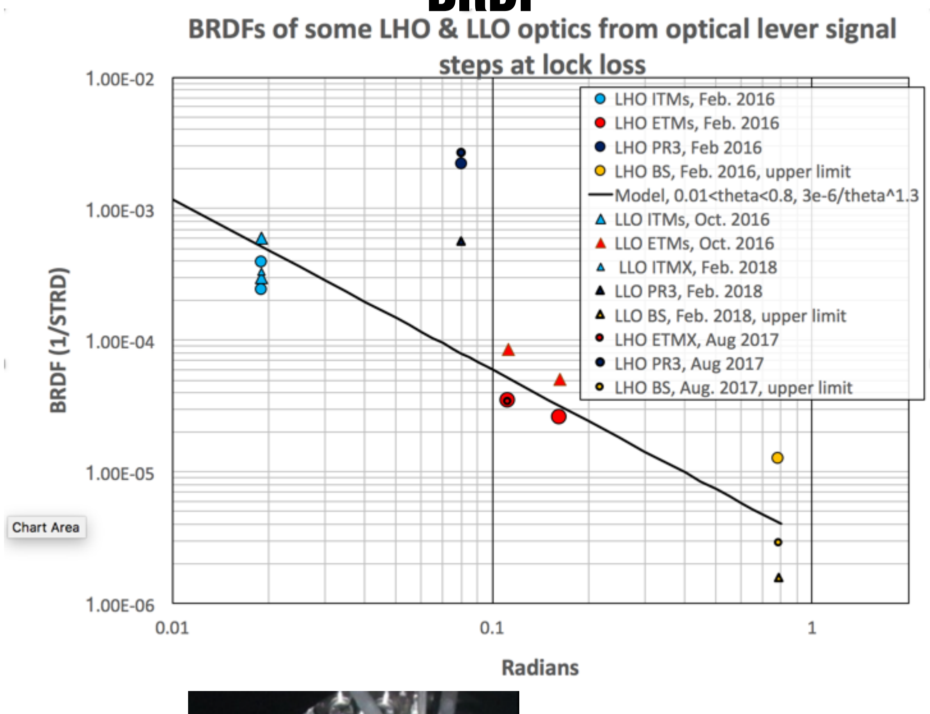


# 4. Glint ranking method

https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=41142

**Weight = BRDF^2 * transfer-to-DARM * relative-power-on-optic * steradians-of-glint * reflector-motion * normalization-factor / distance-optic-to-reflector^2**

## BRDF




## Transfer-to-DARM

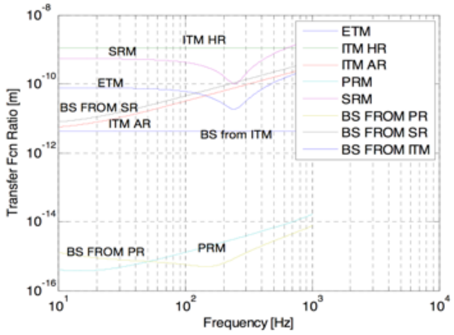



Figure 2: Scattered Light Noise Transfer Functions

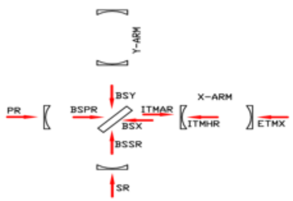
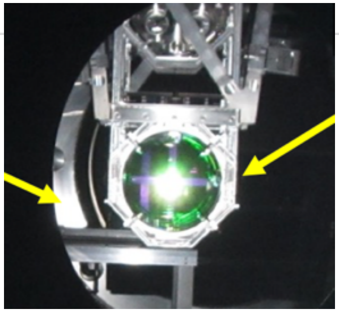



Figure 1: Scattered Light Injection Points

At 100 Hz
Arm cavity..........................1
Dark port..........................0.3
From outside the ETM....0.05
BS SR..............................0.03
CP....................................0.02
BS from ITM...................0.003
PRM...............................1 e-6
BS from PR...................0.8 e-6



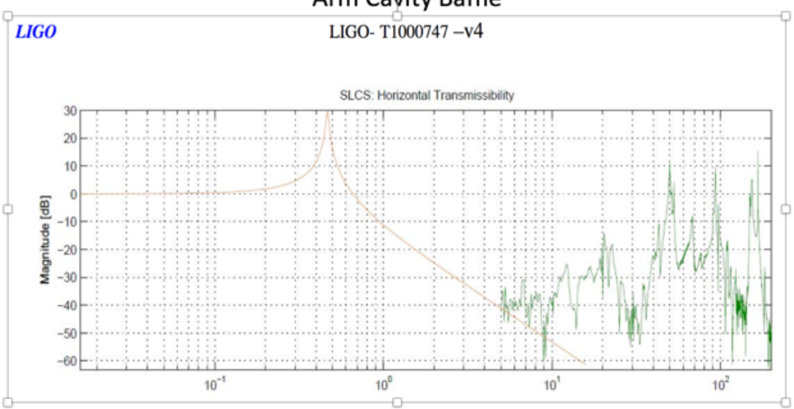
**Steradians-of-glint: photo approx. calibrated to steradians per pixel using known angles, multiplied by pixels in glint. Simplified by assuming all pixels in glints have same value.**

# 4. Glint ranking method

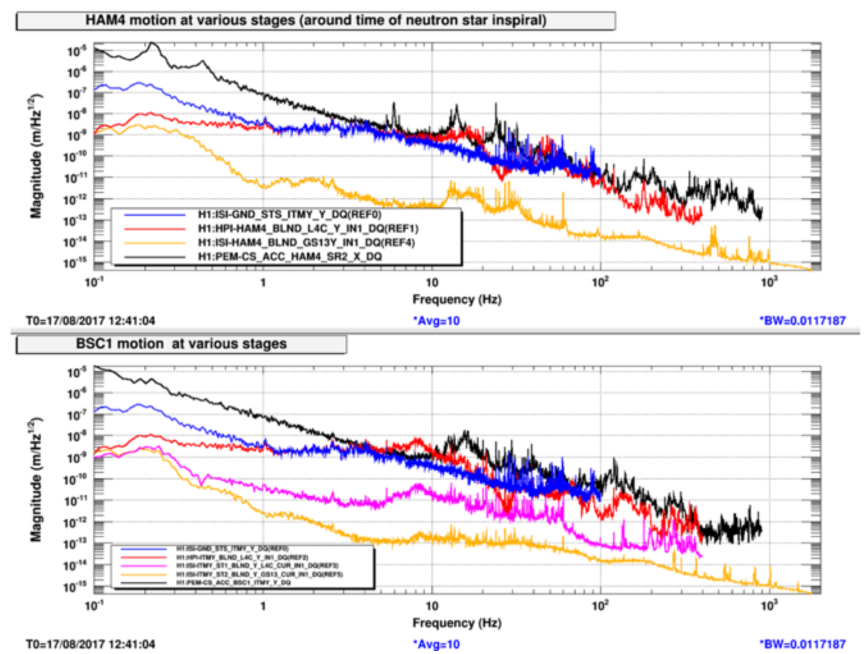
**Weight = BRDF^2 * transfer-to-DARM * relative-power-on-optic * steradians-of-glint * reflector-motion * normalization-factor / distance-optic-to-reflector^2**

## Reflector motion estimate from transfer function at 100 Hz

Arm Cavity Baffle




HAM and BSC




**Some caveats: photo is wide-band, doesn't account for recombination at different optic, doesn't account for stray beams (but pictures show reflectors).**

# Table of weighting factors for wide-angle scattering

| optic from which beam is scattered and recombined, dash gives the direction of the beam being scattered if there are multiple possibilities | retro-reflecting site | weighting | Rough seismic isolation at 100 Hz | sqrt( weighting) x seismic isolation (rough amplitude) |
|---|---|---|---|---|
| BRDF model: 3e-6/theta^1.3 with distance^2 and isolation weighting | | | | |
| ETMY-ITMY | P-Cal periscope glint | 1.00E+00 | 1 | 1.00E+00 |
| ITMX-ETMX | valve seat | 9.48E-01 | 1 | 9.73E-01 |
| ITMX-ETMX | ACB line reflections in near corner of ACB | 3.10E+00 | 0.1 | 1.76E-01 |
| ETMY-ITMY | ACB line reflection near corner | 2.24E+00 | 0.1 | 1.50E-01 |
| ITMX-ETMX | reducing flange by op lev | 1.32E-02 | 1 | 1.15E-01 |
| ETMX-ITMX | ACB line reflection near corner | 1.31E+00 | 0.1 | 1.14E-01 |
| ETMX-ITMX | ACB line reflection far corner | 8.46E-01 | 0.1 | 9.20E-02 |
| ETMY-ITMY | ACB line reflection far corner | 2.52E-01 | 0.1 | 5.02E-02 |
| BS--XY wall | wall with op lev | 1.47E-03 | 1 | 3.83E-02 |
| BS-ITMY | chamber wall | 2.70E-05 | 1 | 5.20E-03 |
| BS-ITMX | BSC3-7-Flange | 1.03E-05 | 1 | 3.21E-03 |
| BS-ITMY | Flange BSC1-8 | 6.50E-06 | 1 | 2.55E-03 |
| ITMX-ETMX | bellows | 6.07E-06 | 1 | 2.46E-03 |
| CPX-BS | TCS mirror | 4.28E-06 | 1 | 2.07E-03 |
| CPY-BS | TCS mirror holder | 3.01E-06 | 1 | 1.73E-03 |
| CPY-BS | ITM elliptical baffle top | 4.91E-05 | 0.1 | 7.01E-04 |
| CPX-BS | ITM elliptical baffle top | 3.06E-05 | 0.1 | 5.53E-04 |
| BS-ITMY | elliptical baffle top | 1.48E-05 | 0.1 | 3.85E-04 |
| BS-SR3 | HAM4 table edge | 7.95E-04 | 0.01 | 2.82E-04 |
| BS-SR3 | HWFS equipment | 1.72E-04 | 0.01 | 1.31E-04 |
| SRM-BS | BSC1-8 flange | 5.39E-09 | 1 | 7.34E-05 |
| CPX-BS | front side of HAM4, lower part visible under elliptical baffle | 4.41E-05 | 0.01 | 6.64E-05 |
| SR2-SRM | baffle reflection | 2.52E-05 | 0.01 | 5.02E-05 |
| CPX-BS | HAM4 table edge visible through elliptical baffle | 2.49E-05 | 0.01 | 4.99E-05 |
| BS-ITMY | cage around test mass | 6.28E-05 | 0.003 | 2.38E-05 |

**High rankings of P-Cal periscope, reduction flange and BS chamber walls agree with shaking results**

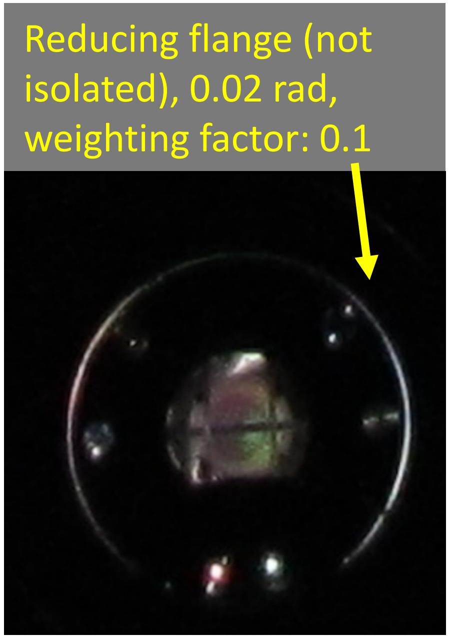
# Glints with weighting of 1

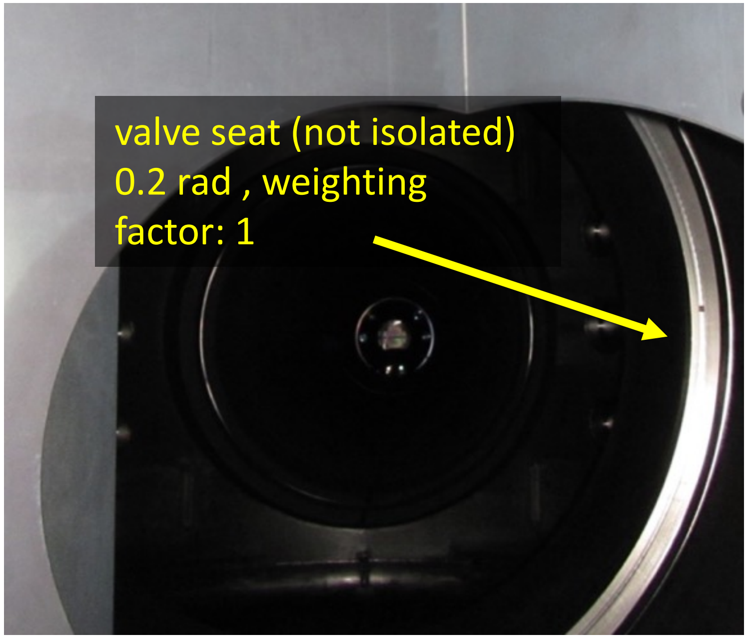
## ETMY towards ITMY, showing P-Cal periscope before upgrade

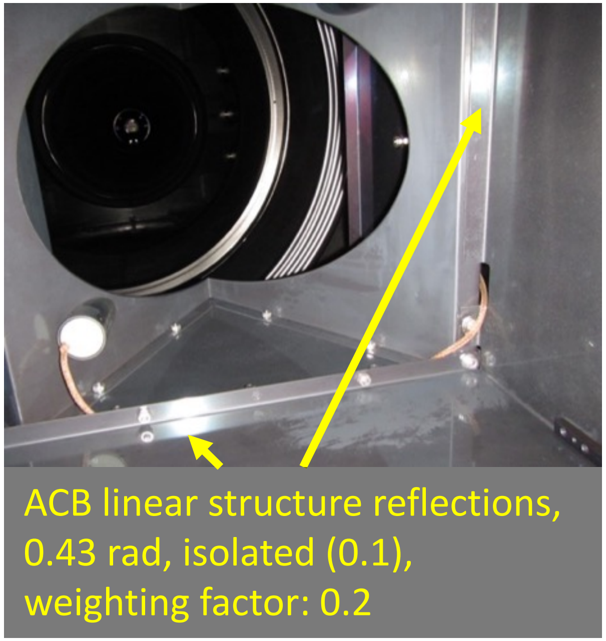
Periscope glints before baffling, no isolation, about 0.06 rad, weighting factor: 1, glints thought to be responsible for raven pecks appearing in DARM. Reflection from gate valve has been blacked out.

# Next highest weighting factors

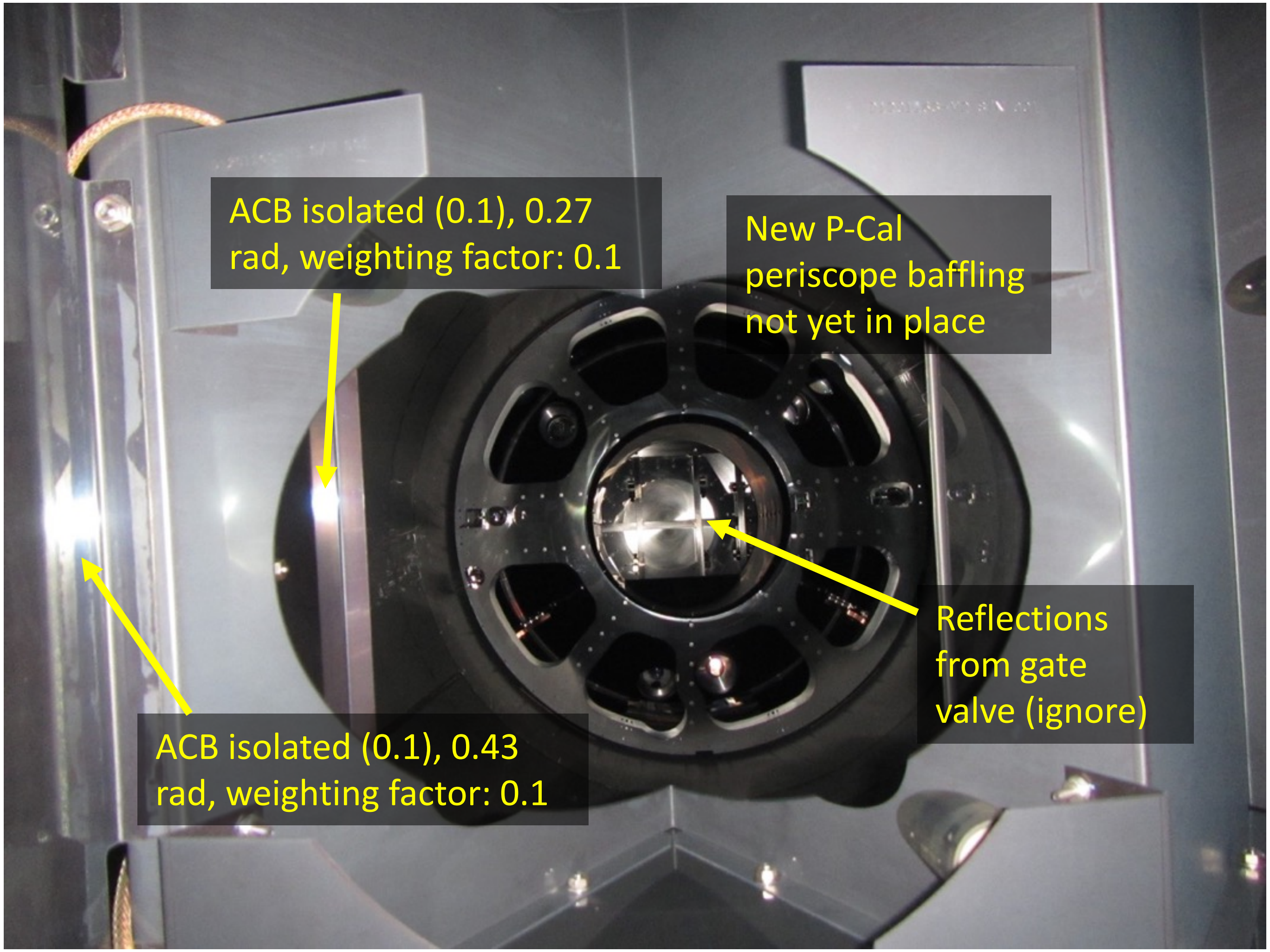
## ITMX looking towards ETMX, similar on other arm

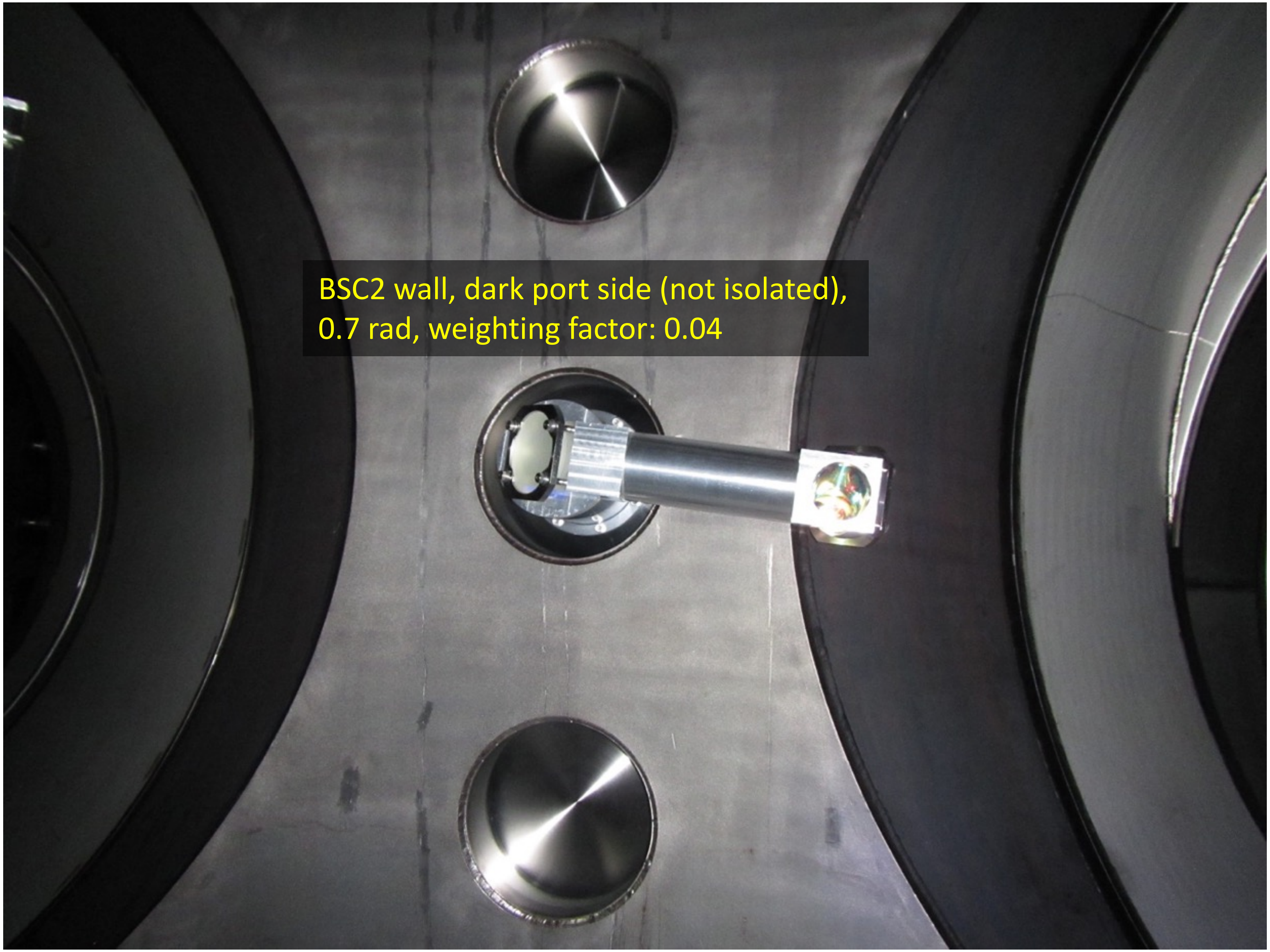


# ETMX towards ITMX




BSC2 wall, dark port side (not isolated),
0.7 rad, weighting factor: 0.04

# Suggested priorities for SLiC

| Stray light mitigation | Comments | Further studies |
|---|---|---|
| 1) OFI shroud for HAM5-6 coupling | 1) OFI actuator injection: lots of DARM noise<br>2) Shaking indicates path that involves HAM5-6 vacuum enclosure (including septum)<br>3) Lots of light seen from port with viewer | Investigate possible role of ZM path (LHO/LLO difference in O2) |
| 2) Improve SQZ beam diverter | Will help with diagnosis of other squeezer stray light, etc. | |
| 3) Nozzle baffle for P-Cal port, blank reduction flange ports, blank BS ports. | 1) Shaking of P-Cal beam nozzle<br>2) Moderate glint rankings | |
| 4) Baffle ring around baffle at reduction flange by ITM optical levers | 1) Moderate glint ranking<br>2) Shaking produces moderate coupling | |
| 5) Baffle BSC2 walls | 1) Moderate glint ranking<br>2) DARM noise from shaking of VE around BSC2 at both sites | Further shaking studies to test wall hypothesis |
| 6) Improve Arm Cavity Baffles, baffle corner reflections and block gate valve seat | 1) High glint ranking<br>2) But no evidence in HEPI shaking tests or noise from shaking gate valve | X and Y HEPI injections at test masses |
| 7) Baffle BS-side faces of HAM3,4 | 1) Glint ranking fairly low,<br>2) No evidence from shaking | |
| 8) Angle P-cal beam windows | | |

Opportunistically: ghost beam on balance mass in front of PR2, Dog clamps / table masses, SR2 Baffle Aperture to HWC, etc.

# Summary from shaking and glint ranking

I. We are doing pretty well for O3, glint ranking and shaking did not uncover any limiting scattering except at LLO HAM5-6 (OFI?).

II. However, glints from ACBs and valve seat were ranked almost as high as the P-Cal periscope and we need to double check that shaking stage zero of TMs doesn't produce noise, and that we are moving the gate valve enough when we shake it.

III. Many of the places of concern, e.g. exposed HAM1-2 septum, are probably not significant concerns.

IV. We suggest focus on output port scattering (OFI?) and any new scattering associated with the squeezers. And continue checking stray beams.

# VI. Other support for astrophysical search groups

A. Continuous (like a calibration line) or Tuesday magnetic injection to determine coupling, for Stochastic estimates of correlated magnetic noise in DARM

B. Likely need new site for LLO LEMI, also for Stochastic

C. Beam tube currents and transients at LLO

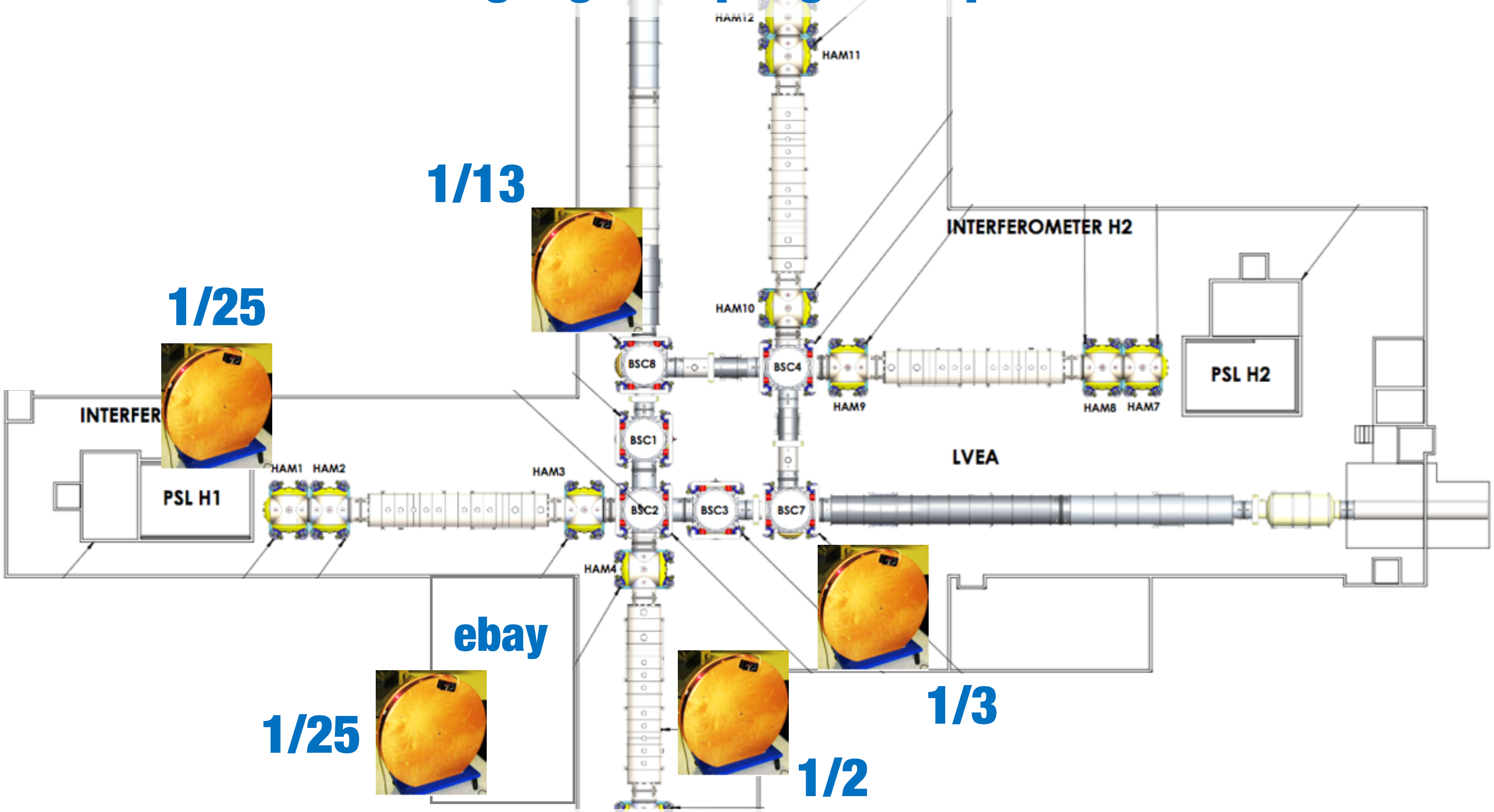
D. Line finding for CW and Stochastic

E. Blip glitches from environmental sources

F. PEM at KAGRA workshop

# A. Ratio of O2 33-53 Hz magnentic coupling, Aug/Nov

**Consistent with reduced coupling in path from ebay to vertex and remaining high coupling in output arm.**

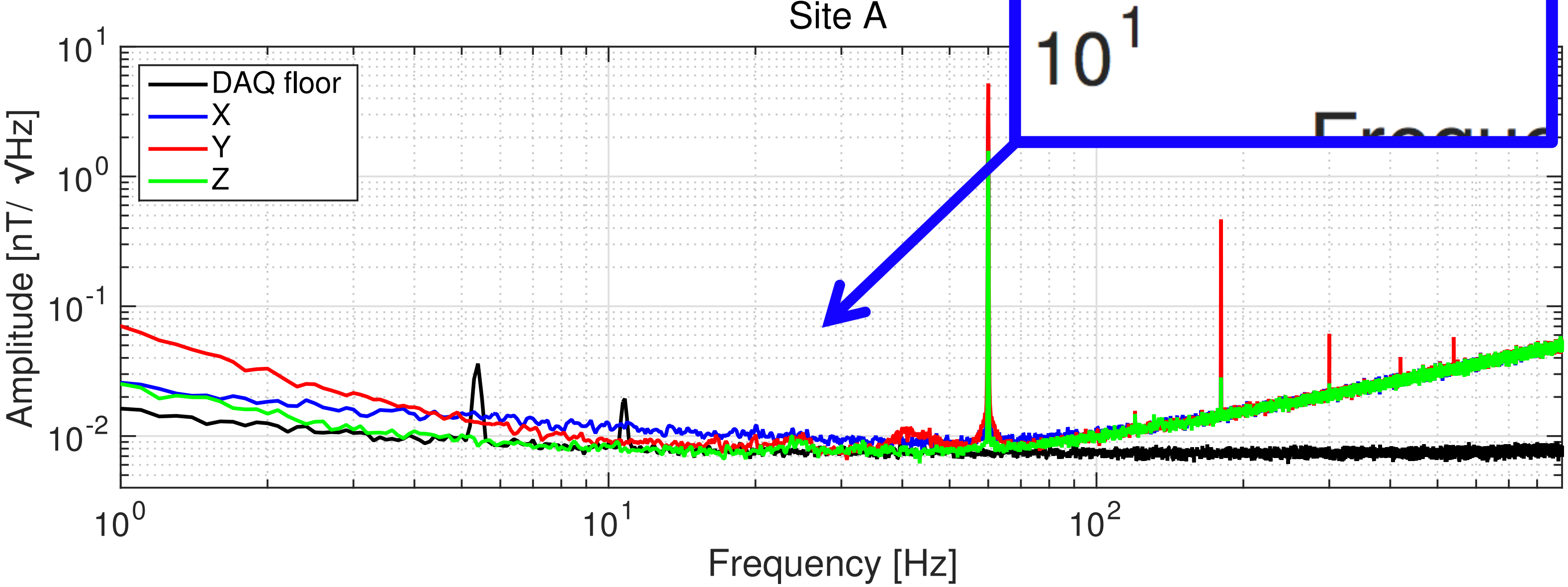



**A possible explanation: HV supplies on ITM ESDs were replaced…**

R. McCarthy F. Clara

**Do we need to continuously inject (like a calibration line) to monitor coupling when we subtract correlated noise from Schumann resonances?**

# B. Investigation of LEMI site along entry road: 20 Hz still present


## Should we be planning off-site location?

# C. DEMCO found and corrected neutral-to-ground break,

## but no reduction seen in glitches on magnetometer - recheck beam tube currents

Paul Corban, Anamaria

# D. Contributions to Paper on O1-O2 line finding

## Identification and mitigation of narrow spectral artifacts that degrade searches for persistent gravitational waves in the first two observing runs of Advanced LIGO

P. B. Covas,[1] A. Effler,[2] E. Goetz,[3,4] P. M. Meyers,[5] A. Neunzert,[3] M. Oliver,[1] B. L. Pearlstone,[6] V. J. Roma,[7]
R. M. S. Schofield,[7] V. B. Adya,[4] P. Astone,[8] S. Biscoveanu,[9,10] T. A. Callister,[11] N. Christensen,[12,13] A. Colla,[14,8]

https://dcc.ligo.org/DocDB/0148/P1700440/005/ALIGO_LinesCombsPaper.pdf

### VI. RESULTS

In this section, we describe examples of particular noise sources that were mitigated between the O1 and O2 data runs, or during the O2 run. For each noise source, a plot showing the improvement of the spectrum in the respective frequencies is also presented.

When a new feature in the detector strain data channel is discovered by using the tools mentioned in the previous section, additional investigations to identify the source of the noise are performed:

1. Determine the Q-factor of the line affecting the search. This helps identify the source and type of equipment that is producing the line. If the Q-factor is above $10^6$, the source is likely to be precision-clocked electronics components, or equipment that is synchronized to GPS. Typical inexpensive clock chips in electronic devices have Q-factors

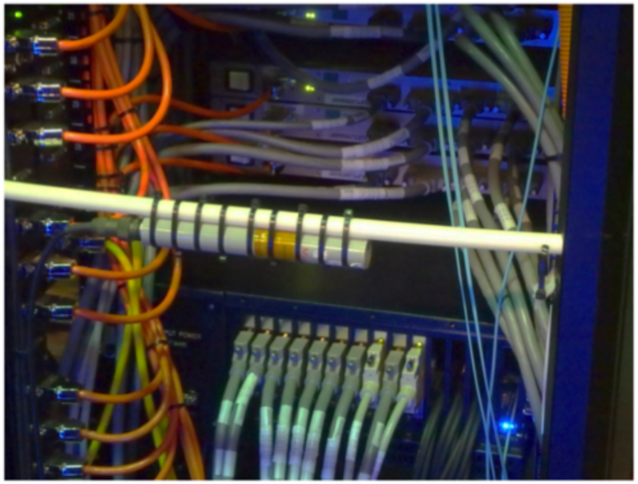
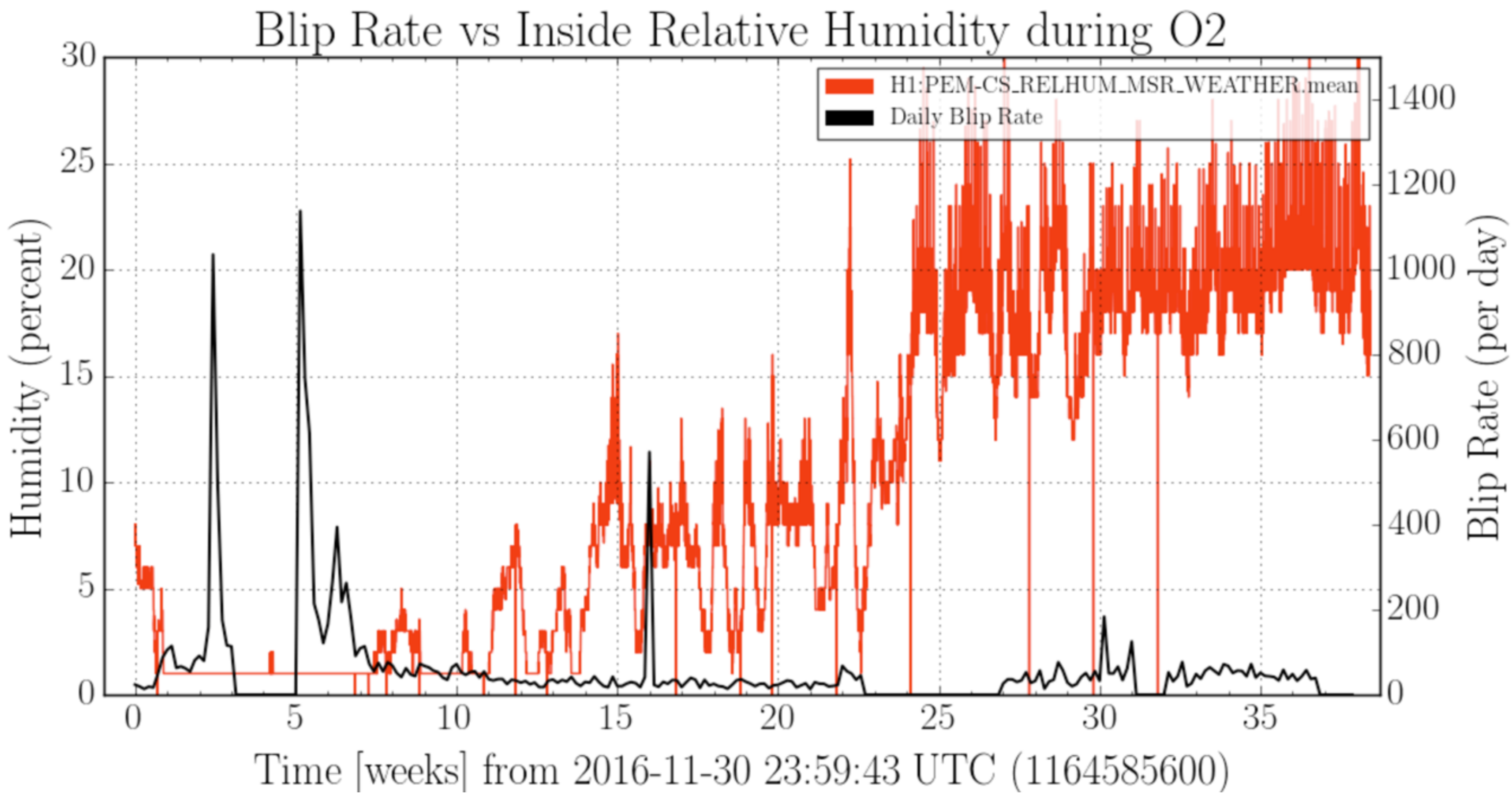


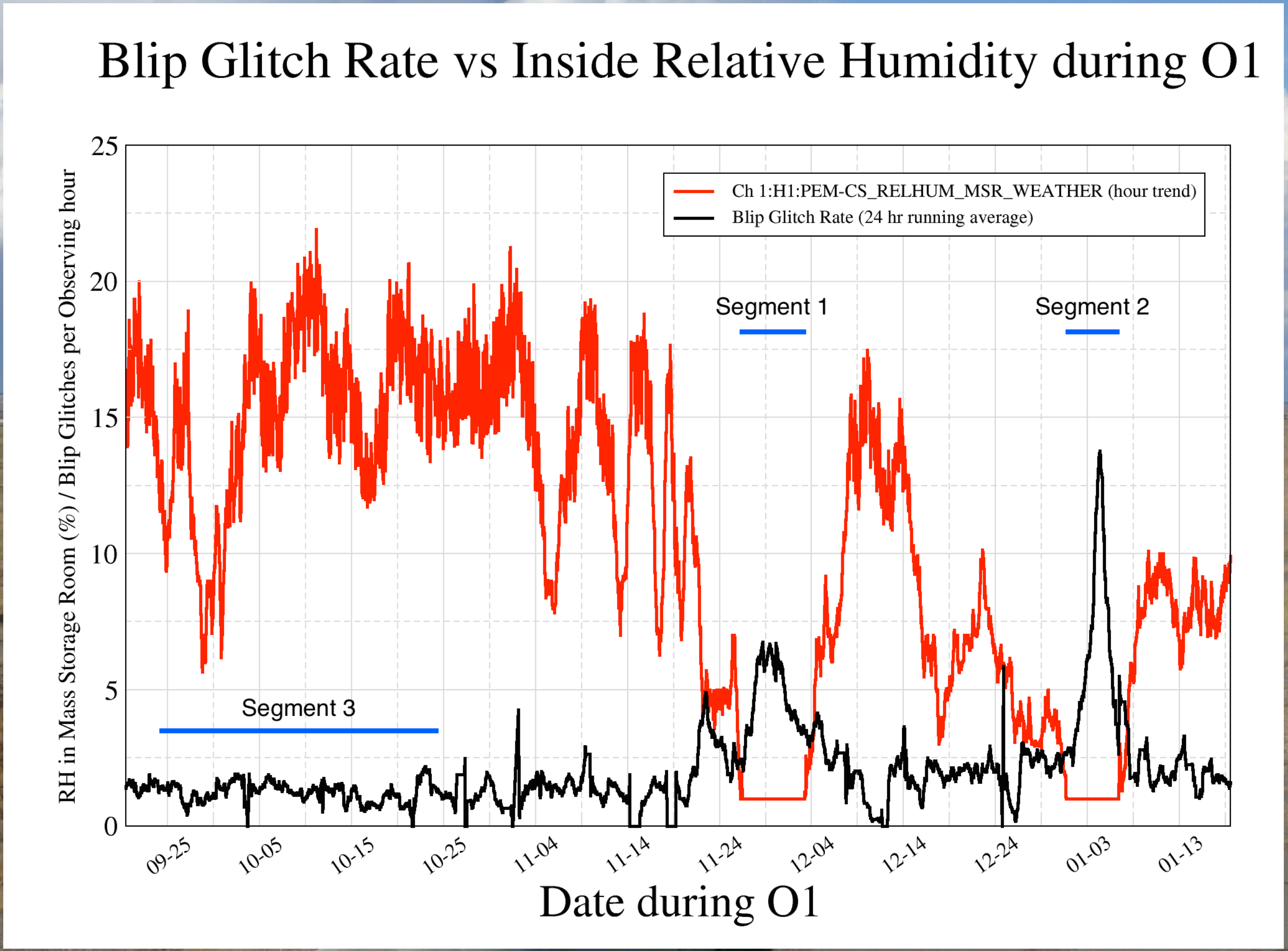
FIG. 3. Method of monitoring electronic components and cables for frequencies of instrumental lines found in the data. A Bartington fluxgate magnetometer (Mag-03 MCES100) is mounted on the horizontal white PVC pipe in the back of an electronics rack containing electronics that control the position of important optics. If the magnetometer detects fields from currents varying at the same frequency as an instrumental line, the source of the line may be in the vicinity. In addition to helping with searches for sources of line artifacts, the magnetometer can indicate that a spectral line is not astrophysical in origin.

# E. O2 high blip-glitch rate with low humidity

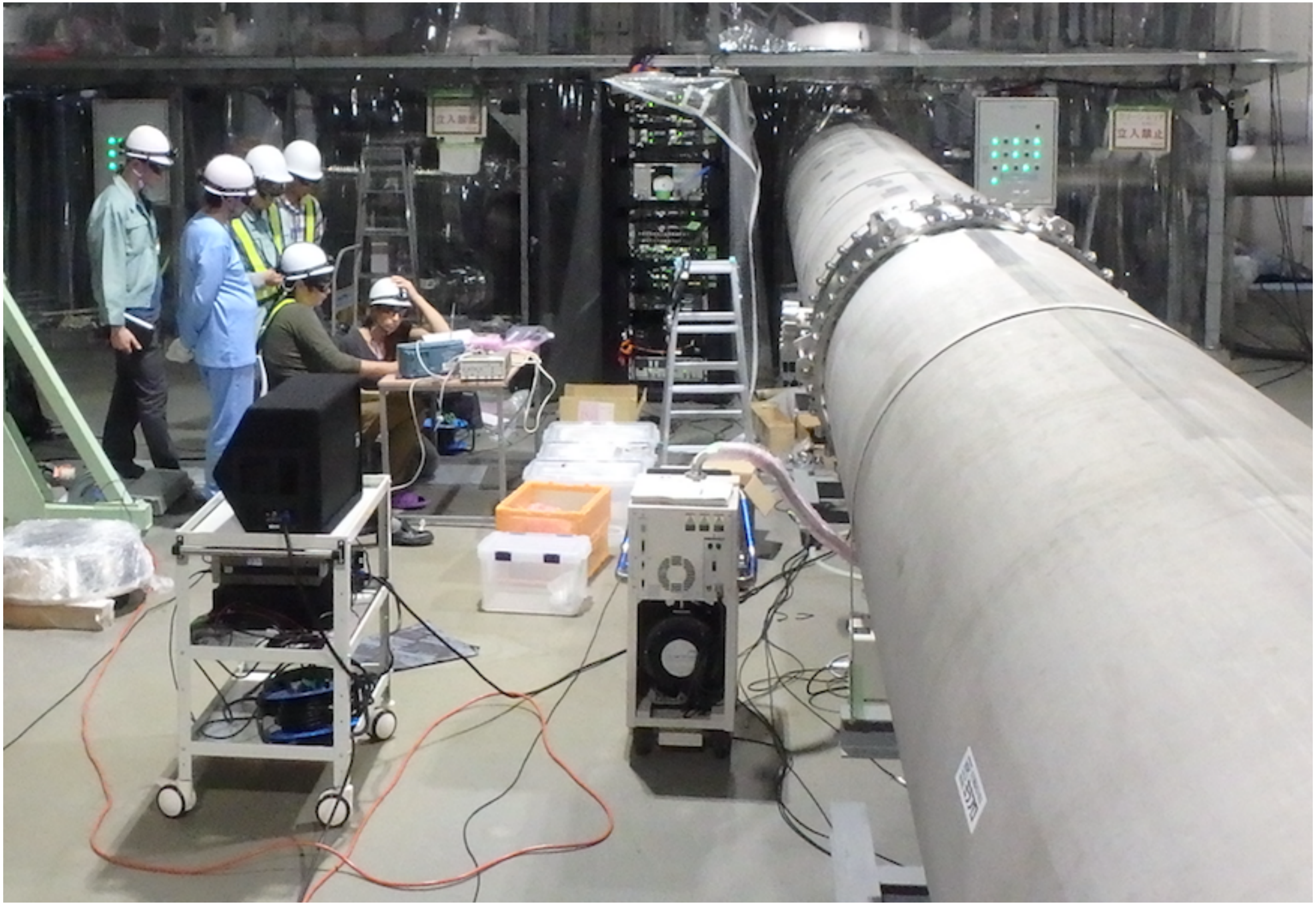
Derek Davis, Laurel White, Miriam Cabero



# Blip glitch studies
# Paul Schale, Jordan Palamos, RS



# F.  PEM at KAGRA workshop



# Outline of results

A. SUGGESTED ACTIONS

1) For PEM channels, use BNC interfaces with a gain of at least 10, and a gain of 100 for the seismometers.
2) Check for clipping at likely sites (EOM/AOM) on PSL table.
3) Improve the PSL table periscope and make table connections more rigid at other optic structures with mass far above the surface (high moment of inertia around the attachment point).
4) Grout the PSL table legs to the floor.
5) Place the power supply racks on vibration isolating feet and also consider isolation for other electronics racks.
6) Improve seismometer mounting and monitor differential motion of the stations.
7) Testing equipment suggestions.

B. AMBIENT VIBRATION AND MAGNETIC LEVELS IN THE KAGRA CORNER STATION, AND A COMPARISON TO LIGO

1) The sound level at KAGRA, with temporary equipment shut down, was measured to be a factor of 2 or 3 below LHO at low (10-100) and high (>1000) frequencies.
2) The seismic signal should be amplified by about 100. The microseismic peak levels appear to be high at KAGRA.
3) Magnetic levels from the mains were significantly larger at KAGRA than LIGO.

C. COUPLING OF ENVIRONMENTAL SIGNALS TO THE IMC

4) The dominant vibration coupling site for the IMC is in the PSL.
5) A Table resonance is responsible for the largest peak in the IMC spectrum, the 80 Hz peak.

# PEM update

## DetChar F2F, August, 2018

I. Restoration of PEM system following install

II. More sensors near coupling sites

III. Improved PEM coupling functions

IV. Plans for BBH vetting in O3

V. Most important PEM-related commissioning

VI. Other support for astrophysical search groups

**Robert Schofield, Philippe Nguyen, Kara Merfeld, Ray Frey, Jordan Palamos, UO, Anamaria Effler, Corey Austin, Terra Hardwick, Valery Frolov, LLO, and many others**