aLIGO HAM-ISI, BSC-ISI, HAM-HEPI and BSC-HEPI matrices

The purpose of the change of basis matrices is to combine local instruments to sense (or drive) the platforms rigid body motions along the axis of the interferometer (in other work they align the sensing basis of each platform with the axis of the interferometer)

The local sensors of a given set of instruments are typically noted H1, H2, H3, V1, V2 ,V3, standing for Horizontal 1 to 3 and Vertical 1 to 3*

The translation and rotations along the axis of the interferometer are noted X,Y,Z, RX,RY,RZ.

The objectives of this document are:

- **To describe the instruments location and orientation**
- **To define which scripts have been used to calculate the change of basis matrices (must define clear location in the svn)**
- **List the matrices values (for each of the two possible platform orientations)**
- **Specify where the matrices are stored in the svn and the Structures names**
- **Specify which scripts to use to load the matrices (populate...)**

*** HEPI sets of 8 instruments noted H1, H2, H3, H4, V1, V2 ,V3, V4 and BSC-ISI Stage 1 T240 set is made of 9 signals noted X1, Y1, Z1, X2, Y2, Z2, X3, Y3, Z3.**

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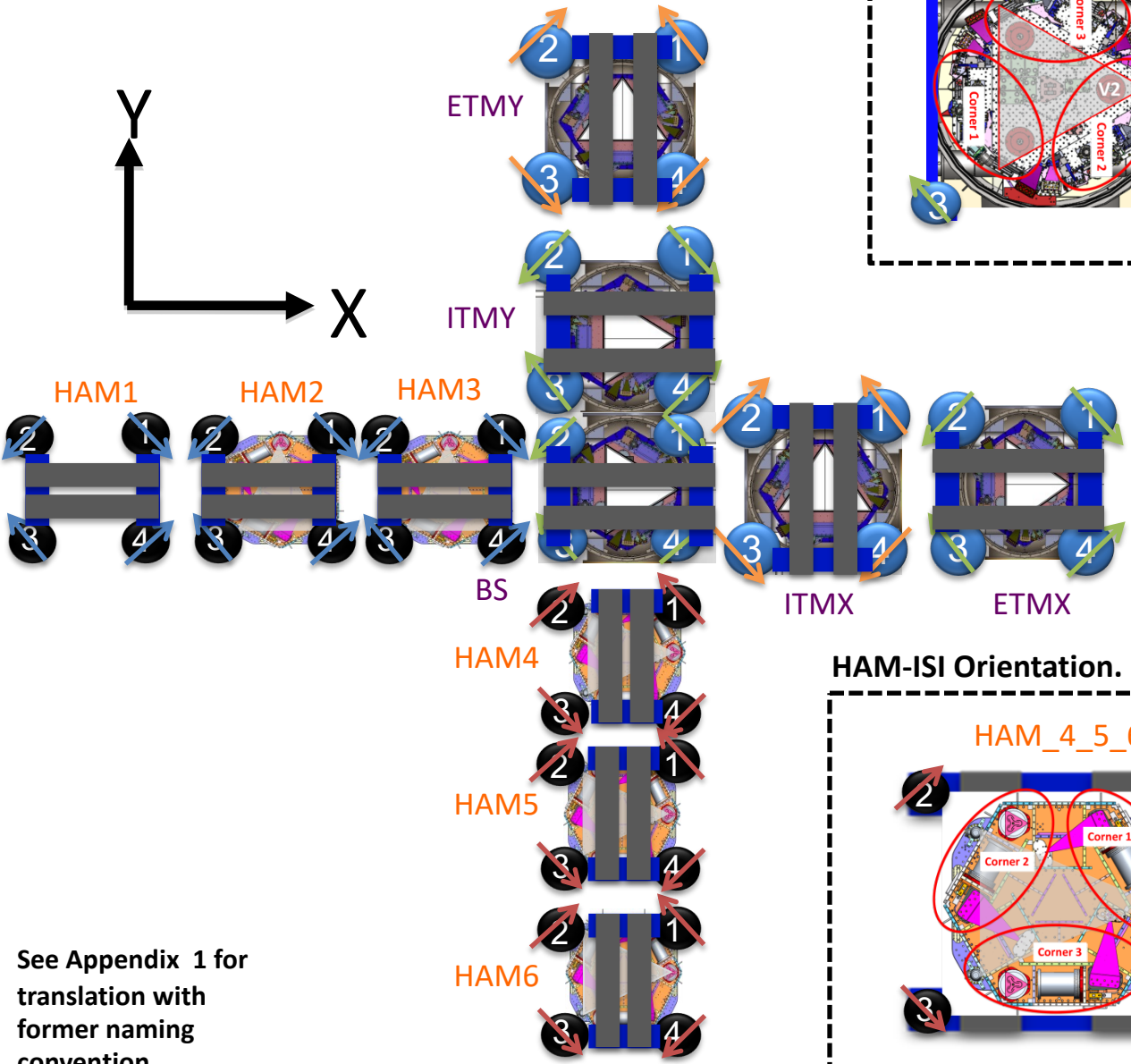
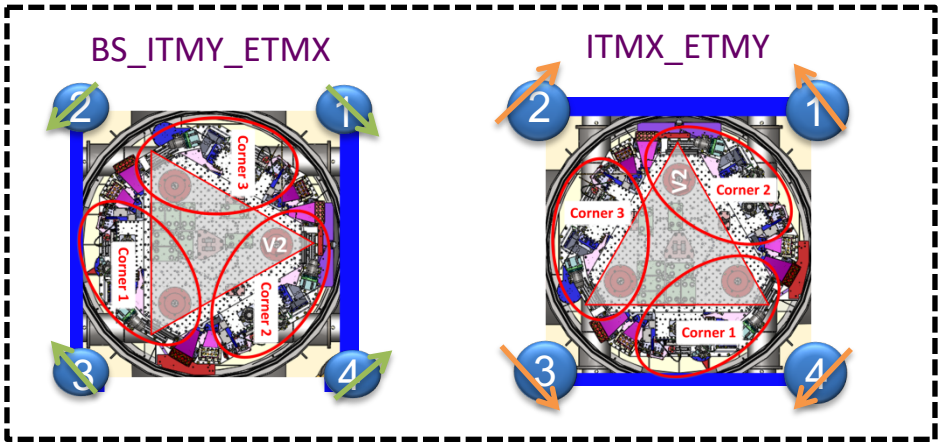
1) Instruments location and orientation

1.0) Modules Orientation

(See G1000125 for mode details)

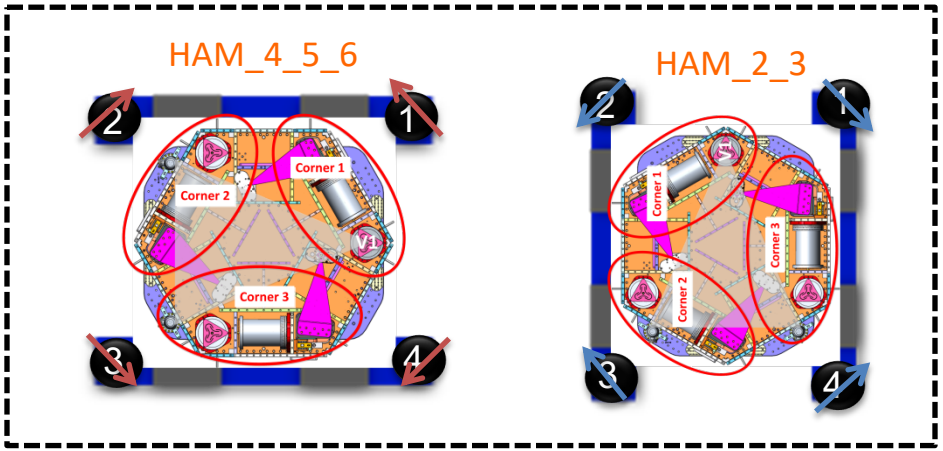


BSC-ISI Orientation.



HEPI Orientation.

HAM-ISI Orientation.



See Appendix 1 for translation with former naming convention.

Summary of Position Sensors signal "sign":

- **HAM-HEPI:** Positive RZ motion of HEPI Stage makes +H1, -H2, +H3 and -H4 IPS signals* for HAM 4,5,6
- **HAM-HEPI:** Positive RZ motion of HEPI Stage makes -H1, +H2, -H3 and +H4 IPS signals* for HAM 1,2,3
- **HAM-ISI:** Positive RZ motion of Stage 1 makes negative CPS signals* for all chambers
- **BSC-HEPI:** Positive RZ motion of HEPI Stage makes +H1, -H2, +H3 and -H4 IPS signals* for ITMX, ETMY BSC
- **BSC-HEPI:** Positive RZ motion of HEPI Stage makes -H1, +H2, -H3 and +H4 IPS signals* for BS, ITMY, ETMX
- **BSC-ISI:** Positive RZ motion of Stage 1 makes negative CPS signals* for all chambers
- **BSC-ISI :** Positive RZ motion of Stage 2 makes positive CPS signals* for all chambers

- HAM-HEPI, BSC-HEPI, HAM-ISI, BSC-ISI:

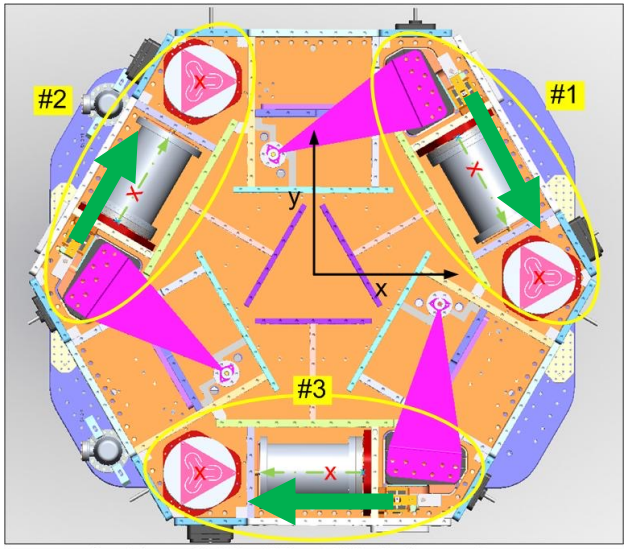
Positive Z motion makes positive PS signal in all local vertical sensors* (for all stages & all chambers)

These signs are checked during the assembly and testing process by pushing on the moving stages and watching the local sensors readouts. The position sensors are then used during the commissioning process to verify and correct if necessary the sign of all other instruments (actuators, geophones and seismometers)

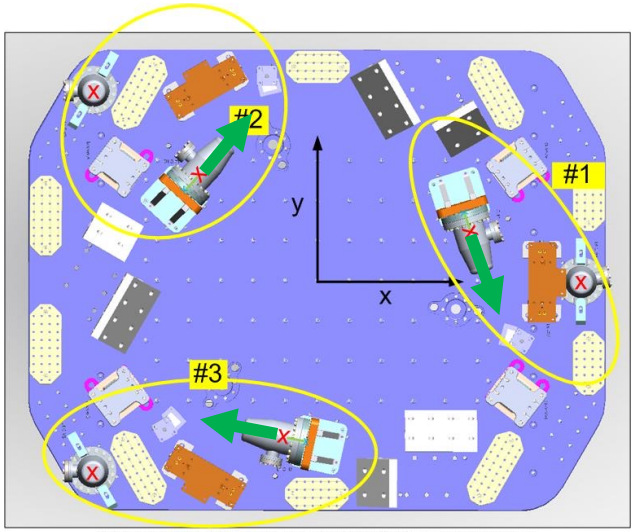
*as read on the IN1 channel of the input filters

Details about horizontal HAM-ISI Instrumentation / Controls coordinates

- The controls coordinate system's XY plane is set to have the Z=0 origin aligned with the Stage 1 horizontal actuator plane, 218 mm below the optical table surface
- Positive RZ motion of Stage 1 makes negative local CPS signals. (Sensor is on Stage 0, target is on Stage 1, +RZ motion of stage 1 closes the gap.) The CPS sensors direction vectors are therefore negatively-oriented tangents as shown by the green arrows in the figure in the left. (-60 degrees angle in Corner 1)
- For the calculation of the actuator matrices, it is assumed that each actuator is in the same orientation as its local CPS. If a local to local transfer function* shows otherwise, the actuator sign would be corrected in the "symmetrization" filter located in the actuator's output filter bank.
- For the calculation of the GS13 matrices, it is assumed that each GS13 instrument is in the same orientation as its local CPS and actuator (+270 degrees phase at low frequency). If the local to local transfer function* shows otherwise, the GS13 instrument sign would be corrected in the "symmetrization" filter located in the GS13 input filter bank.
- For the calculation of the L4C matrices, it is assumed that the L4Cs are in the same orientation as the CPS, actuators, and GS13's (tangent oriented negatively as shown by the green arrows). If the local to local transfer function* shows otherwise, the L4C instrument sign would be corrected in the "symmetrization" filter located in the L4C input filter bank.



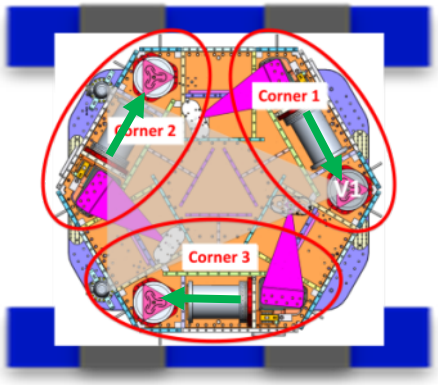
Stage 1 Sensors GS-13 H and V, Stage 0-1 H Position Sensors and Actuators

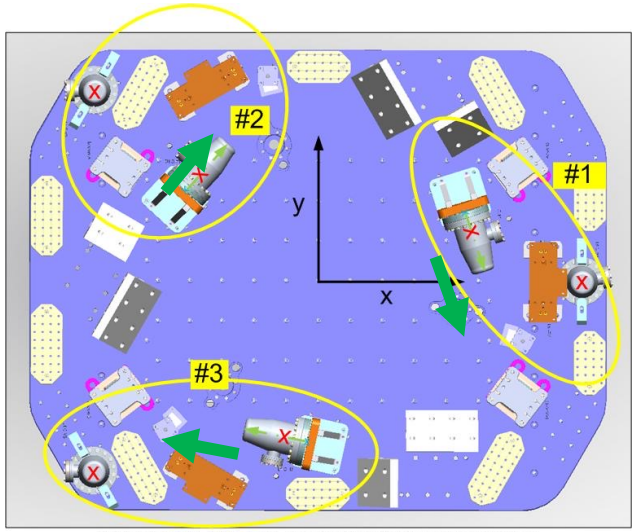


Stage 0 Sensors L4-C H and V, Stage 0-1 V Position Sensors and Actuators

* Local to local transfer function: from local actuator "Exc channel" to "IN1 channel" in the local sensor input filter's. Only the "Comp filter" must be engaged in the actuator bank (to partially revert the coil driver and actuator frequency response). See example in appendix 2.

aLIGO HAM-ISI Sensors & Actuators Location





Stage 0 Sensors L4-C H and V, Stage 0-1 V Position Sensors and Actuators

HAM_4_5_6 instruments location and direction:

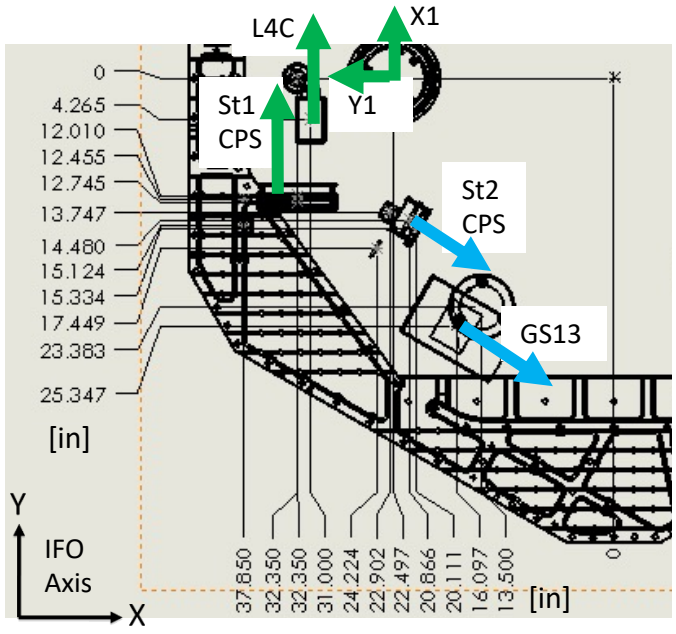
Sensor	X [m]	Y [m]	Z [m]	Direction
Actuator H1	0.52342	0.64154	0.00000	-60 deg to X
Position sensor H1	0.53071	0.66058	-0.20358	-60 deg to X
GS-13 H1	0.58849	0.33960	-0.03334	-60 deg to X
L4-C H1	0.48582	0.14852	-0.40043	-72.5 deg to X
Actuator V1	0.71120	0.00000	-0.38119	0 deg to Z
Position sensor V1	0.64703	-0.18553	-0.39402	0 deg to Z
GS13 V1	0.78740	0.00000	-0.04272	0 deg to Z
L4C V1	0.83502	0.00000	-0.41821	0 deg to Z
L4C V2	0.71120	0.60325	-0.41821	0 deg to Z
L4C V3	-0.71120	-0.60325	-0.41821	0 deg to Z

Note that L4C V1, V2 and V3 are not 120 degrees apart and not on the same radius.

Notes: HAM 4,5,6 table orientation used for reference. All measurements originated at the center point of the Optics Table on the optics mounting side. The measurement termination locations are as follows: x,y,z center point (origin) of the Actuator field assembly; center point of the face of the Displacement Sensor Target closest to the Sensor; values for seismometers are taken at the approximate center of mass of the proof mass based on SW models (red center points or X)

1.2) aLIGO BSC-ISI Sensors & Actuators

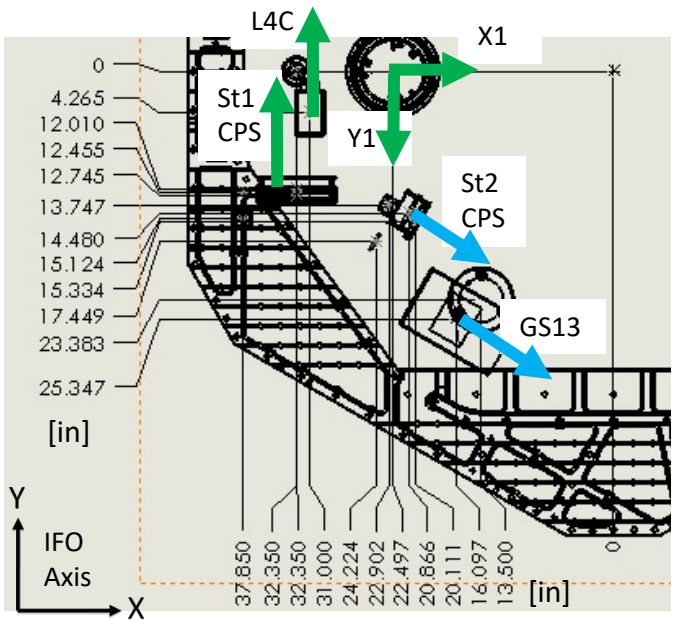
- The coordinate system's origin of Stage 1 is aligned with the Stage 1 horizontal actuators plane located (8.995" above the optical table).
- The coordinate system's origin of Stage 2 is aligned with the Stage 2 horizontal actuators plane (7.188" above the optical table).
- Positive RZ motion of Stage 1 makes negative local CPS signals*. The CPS sensors direction vectors are therefore negatively-oriented tangents as shown by the green arrows in the figure in the left.
- Positive RZ motion of Stage 2 makes positive local CPS signals**. The CPS sensors direction vectors are therefore positively-oriented tangents as shown by the green arrows in the figure in the left.
- For the calculation of the actuators matrices, it is assumed that each actuator is in the same orientation as its local CPS. If a local to local transfer function* shows otherwise, the actuator sign would be corrected in the "symetrization" filter located in the actuator's output filter bank.
- For the calculation of the GS13 and L4C matrices, it is assumed that each instrument is in the same orientation as it local CPS and actuator. If the local to local transfer function* shows otherwise, the instrument sign would be corrected in the "symetrization" filter located in the input filter bank.
- For the calculation of the T240 matrices, it is assumed that the X1 is in the same orientation as the CPS, and that Y1 points radially outward. If the local to local transfer function* shows otherwise, the Linstrument sign would be corrected in the "symetrization" filter located in the input filter bank.



* Positive Stage 1 RZ motion makes negative CPS signal in all three corners. (Sensor on Stage 0, target on Stage 1, +RZ closes the gap and reduces the signal). This is true for both orientations.

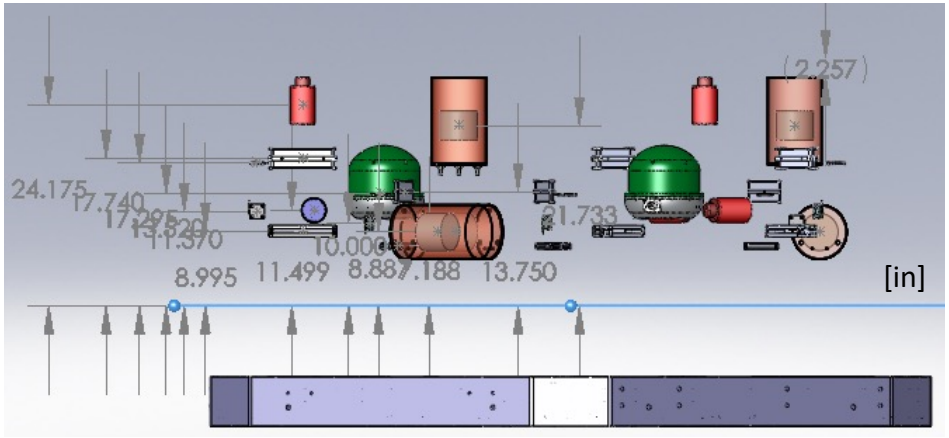
** Positive Stage 2 RZ motion makes positive CPS signal in all three corners. (Sensor on Stage 1, target on Stage 2, +RZ opens the gap and increases the signal). This is true for both orientations.

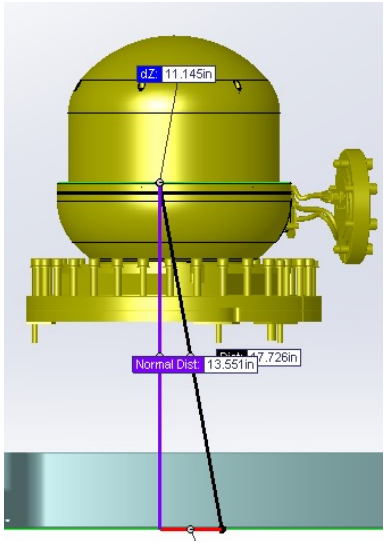
1.2) aLIGO BSC-ISI Sensors & Actuators



BS, ITMY, ETMX instruments location and direction:

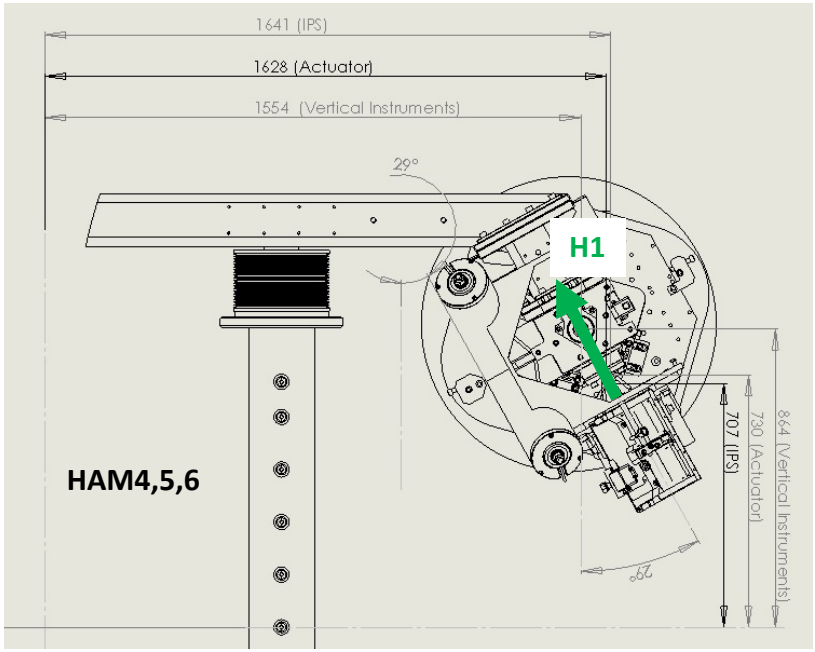
	X [m]	Y [m]	Z [m]	Direction	Notes
Stage 0-1 Act H1	-0.8217	-0.3051	0.0000	90 deg to X	Center Bobbin
Stage 0-1 CPS H1	-0.9614	-0.3164	0.0603	90 deg to X	Center Face of sensor
T240 (X1,Y1,Z1)	-0.5714	0.0000	0.1160	-90 deg to X	Center XY, Z-TBD
L4C H1	-0.7874	-0.1083	0.0600	90 deg to X	Center
Stage 0-1 Act V1	-0.8217	-0.3237	0.2221	0 deg to Z	Center Bobbin
Stage 0-1 CPS V1	-0.9614	-0.3841	0.2108	0 deg to Z	Center Face of sensor
L4C V1	-0.8217	0.0000	0.3855	0 deg to Z	Center
Stage 1-2 Act H1	-0.5300	-0.3678	0.0000	-30 deg to X	Center Bobbin
Stage 1-2 CPS H1	-0.6153	-0.4432	0.0714	-30 deg to X	Center Face of sensor
GS13 H1	-0.4089	-0.6438	0.0432	-30 deg to X	CG
Stage 1-2 Act V1	-0.5108	-0.3895	0.1667	0 deg to Z	Center Bobbin
Stage 1-2 CPS V1	-0.5817	-0.3492	0.1608	0 deg to Z	Center Face of sensor
GS13 V1	-0.3429	-0.5939	0.3694	0 deg to Z	CG

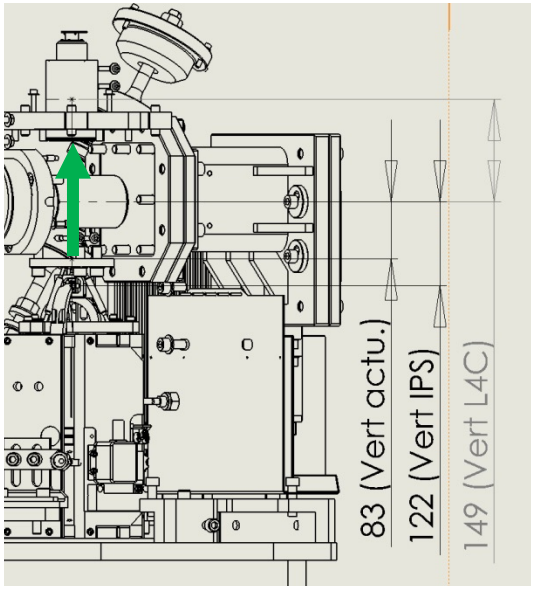




T240 center is about 13.551” above the optical table, that is 4.556” above the Stage 1 Actuator Plane, that is 0.116 m above the Stage 1 Actuator Plane.

1.3) aLIGO HAM-HEPI Sensors & Actuators





HAM4,5,6 instruments location and direction:

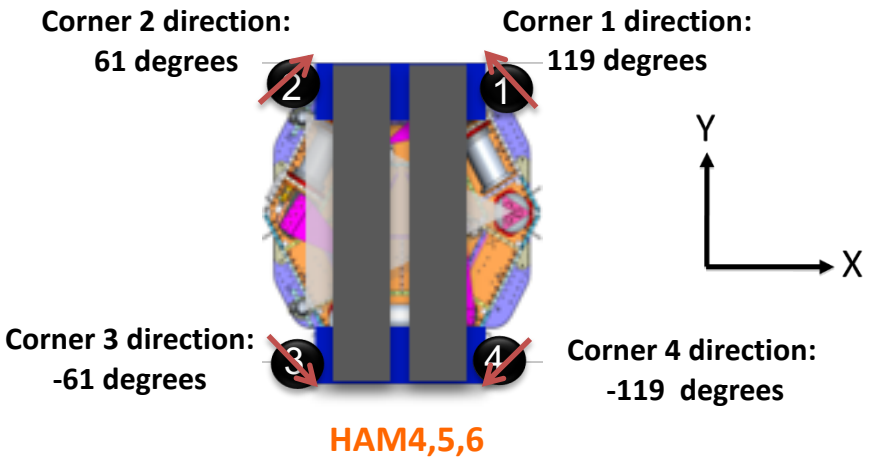
Sensor	X [m]	Y [m]	Z [m]	Angle
Actuator H1	1.628	.730	0	119 deg to X
Position sensor H1	1.641	.707	0	119 deg to X
L4-C H1	1.554	.864	0	119 deg to X
Actuator V1	1.554	.864	-0.083	0 deg to Z
Position sensor V1	1.554	.864	-0.122	0 deg to Z
L4C V1	1.554	.864	0.149	0 deg to Z

Coordinate system's origin is aligned with horizontal actuators plane

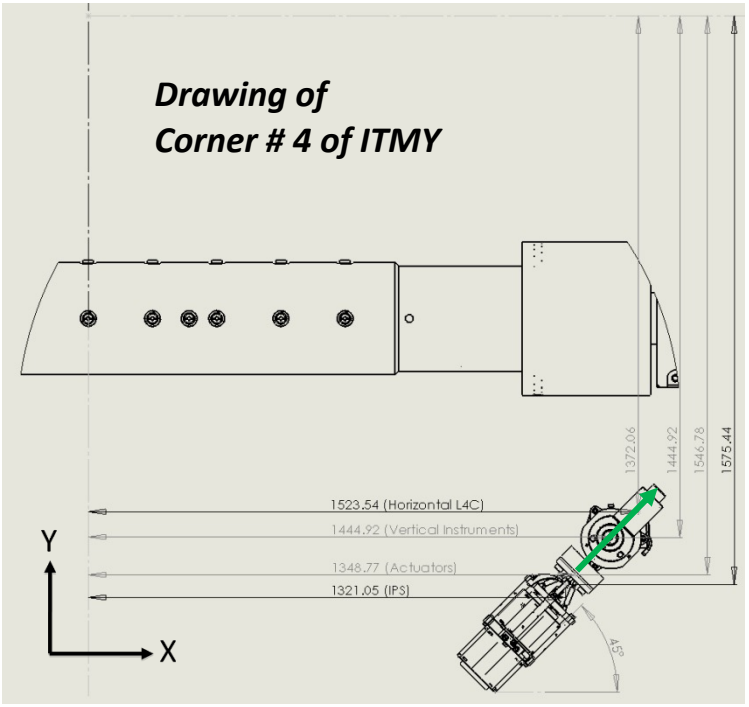
For the Ham 4,5,6 chambers, Positive RZ motion makes +H1, -H2, +H3 and -H4 IPS signals.

For the calculation of the actuators matrices, it is assumed that each actuator is in the same orientation as its local IPS. If a local to local transfer function shows otherwise, the actuator sign would be corrected in the "symetrization" filter located in the actuator's output filter bank.

For the calculation of the L4C matrices, it is assumed that the L4Cs are in the same orientation as the CPS. If the local to local transfer function shows otherwise, the L4C instrument sign would be corrected in the "symetrization" filter located in the L4C input filter bank.



1.4) aLIGO BSC-HEPI Sensors & Actuators



BS, ITMY, ETMX instruments location and direction:

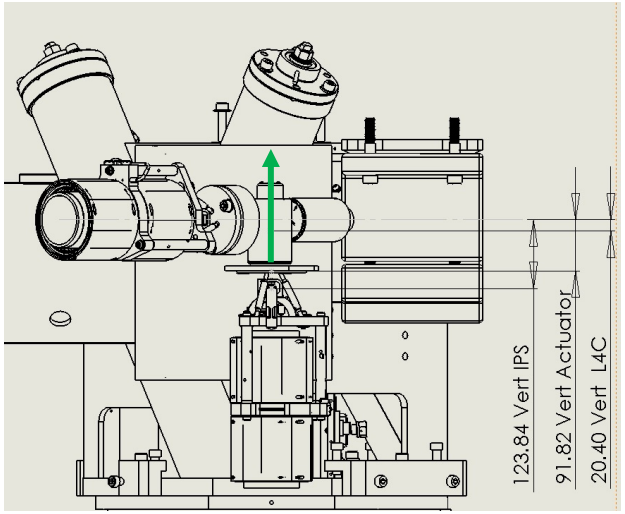
Sensor	X [m]	Y [m]	Z [m]	Angle
Actuator H1	1.348	1.547	0	-45 deg to X
Position sensor H1	1.321	1.575	0	-45 deg to X
L4-C H1	1.523	1.372	0	-45 deg to X
Actuator V1	1.445	1.445	-0.092	0 deg to Z
Position sensor V1	1.445	1.445	-0.123	0 deg to Z
L4C V1	1.445	1.445	0.02	0 deg to Z

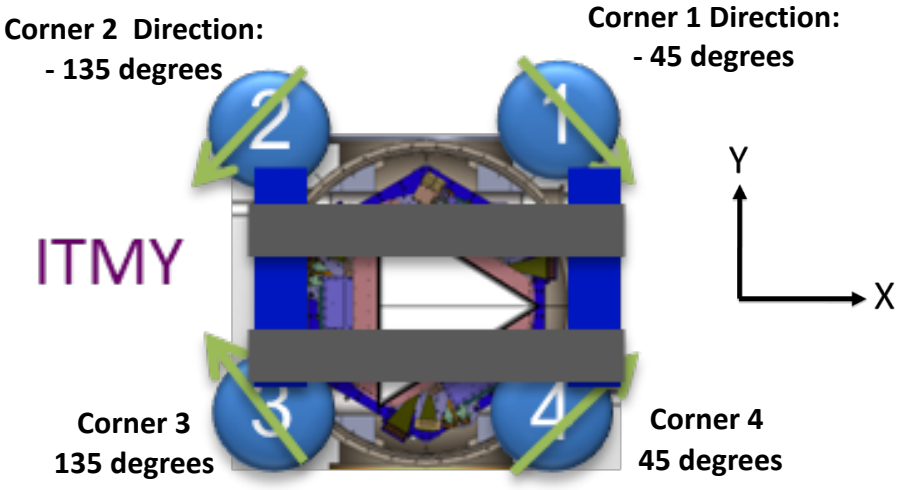
Coordinate system's origin is aligned with horizontal actuators plane

For the BS, ITMY, ETMX , Positive RZ motion makes -H1, +H2, -H3 and +H4 IPS signals.

For the calculation of the actuators matrices, it is assumed that each actuator is in the same orientation as its local IPS. If a local to local transfer function shows otherwise, the actuator sign would be corrected in the "symetrization" filter located in the actuator's output filter bank.

For the calculation of the L4C matrices, it is assumed that the L4Cs are in the same orientation as the CPS. If the local to local transfer function shows otherwise, the L4C instrument sign would be corrected in the "symetrization" filter located in the L4C input filter bank.





2) Change of basis calculation
And scripts

2.1) Calculations

Sensors (1/3)

- Platform's rigid body motion in the Cartesian basis: $C = \{x \;\; y \;\; z \;\; R_x \;\; R_y \;\; R_z\}'$

  - The origin is on the vertical axis of symmetry, and in the horizontal actuators plan
  - Units are $[\mathrm{m}]$ for the translation, $[\mathrm{rad}]$ for the rotation (or any time derivatives of these respective units)
  - The order $\{x \;\; y \;\; z \;\; R_x \;\; R_y \;\; R_z\}'$ will be swapped to $\{x \;\; y \;\; R_z \;\; z \;\; R_x \;\; R_y\}'$ at the end of the calculations

- Measurements in the local basis: $L = \{l_{h1} \;\; l_{h2} \; l_{h3} \; l_{v1} \; l_{v2} \; l_{v3}\}'$

  - Units are $[\mathrm{m}]$ for all measurements (or any time derivatives of these units)

Sensors (2/3)

- The sensor location in the Cartesian basis is noted: $A_i = \{a_i \;\; b_i \;\; c_i\}'$
  - For $i = h_1, h_2, \ldots, v_3$
  - Units are $[\mathrm{m}]$
- The sensor direction in the Cartesian basis is noted: $J_i = \{j_i \;\; k_i \;\; l_i\}'$
  - For $i = h_1, h_2, \ldots, v_3$
  - Direction vector amplitude is unity $|J_i|$
- The motion of the sensor located in A_i is:

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix} + \begin{Bmatrix} Rx \\ Ry \\ Rz \end{Bmatrix} \times A_i = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} - A_i \times \begin{Bmatrix} Rx \\ Ry \\ Rz \end{Bmatrix} = P_i \, C$$

With: $P_i = [\, I(3) \quad | \quad -Cross(A_i)]$ Where: $Cross(A_i) = \begin{bmatrix} 0 & -c_i & b_i \\ c_i & 0 & -a_i \\ -b_i & +a_i & 0 \end{bmatrix}$

$$P_i = \begin{bmatrix} 1 & 0 & 0 & 0 & c_i & -b_i \\ 0 & 1 & 0 & -c_i & 0 & a_i \\ 0 & 0 & 1 & b_i & -a_i & 0 \end{bmatrix}$$

Sensors (3/3)

- The measurement of the sensor located in A_i is the motion projected on the direction of the sensor:

$$l_i = J_i' \, P_i \, C$$

- The sensor matrix S (such as $L = S \, C$) is made of lines of $J_i' \, P_i$:

$$S = \begin{bmatrix} J_{h1}' & P_{h1} \\ J_{h2}' & P_{h2} \\ \cdots & \\ J_{v3}' & P_{h3} \end{bmatrix}$$

- The Local to Cartesian matrix is S^{-1}:

$$C = S^{-1} \, L$$

- Units are dimensionless $[\mathrm{m/m}]$ for the components of the first three lines of S^{-1}
- Units are $[\mathrm{rad/m}]$ for the components of the last three lines of S^{-1}

(or any time derivatives of these units)

Actuators (1/3)

- Platform's forces in the Cartesian basis: $F_C = \left\{F_x \;\; F_y \;\; F_z \;\; \tau_x \;\; \tau_y \;\; \tau_z \right\}'$
  - The origin is on the vertical axis of symmetry, and in the horizontal actuators plan
  - Units are $[\mathrm{N}]$ for the forces, $[\mathrm{N.m}]$ for the torques
  - The order $\left\{F_x \;\; F_y \;\; F_z \;\; \tau_x \;\; \tau_y \;\; \tau_z \right\}'$ will be swapped to $\left\{F_x \;\; F_y \;\; \tau_z \;\; F_z \;\; \tau_x \;\; \tau_y \right\}'$ at the end of the calculations
- Forces in the local basis: $F_L = \{F_{h1} \;\; F_{h2} \; F_{h3} \;\; F_{v1} \; F_{v2} \; F_{v3}\}'$
  - Units are $[\mathrm{N}]$ for all forces
- The actuators location in the Cartesian basis is noted: $A_i = \{a_i \;\; b_i \;\; c_i\}'$
  - For $i = h_1, h_2 \ldots$
  - Units are $[\mathrm{m}]$
- The actuators direction in the Cartesian basis is noted: $J_i = \{ j_i \;\; k_i \;\; l_i\}'$
  - For $i = h_1, h_2 \ldots$
  - The amplitude of the direction vector is unity: $| J_i |$

Actuators (2/3)

- The forces at the center of the Cartesian basis can be written using the direction vectors J_i:

$$\begin{Bmatrix} F_x \\ F_y \\ F_z \end{Bmatrix} = [\, J_{h1} \quad \dots \quad J_{v3}] \begin{Bmatrix} F_{h1} \\ \dots \\ F_{v3} \end{Bmatrix}$$

- The moments at the center of the Cartesian basis can be written using the direction vectors J_i:

$$\begin{Bmatrix} \tau_x \\ \tau_y \\ \tau_z \end{Bmatrix} = [\, A_{h1} \times J_{h1} \quad \dots \quad A_{v3} \times J_{v3}] \begin{Bmatrix} F_{h1} \\ \dots \\ F_{v3} \end{Bmatrix}$$

- The drive matrix D (such as $F_C = D\ F_L$) made of columns of $Q_i\ J_i$:

$$D = [Q_{h1}\ J_{h1} \quad \dots \quad Q_{v3}\ J_{v3}]$$

With: $Q_i = \begin{bmatrix} I(3,3) \\ Cross(A_i) \end{bmatrix}$ where: $Cross(A_i) = \begin{bmatrix} 0 & -c_i & b_i \\ c_i & 0 & -a_i \\ -b_i & +a_i & 0 \end{bmatrix}$

Actuators (3/3)

- The Cartesian to Local matrix is D^{-1}:

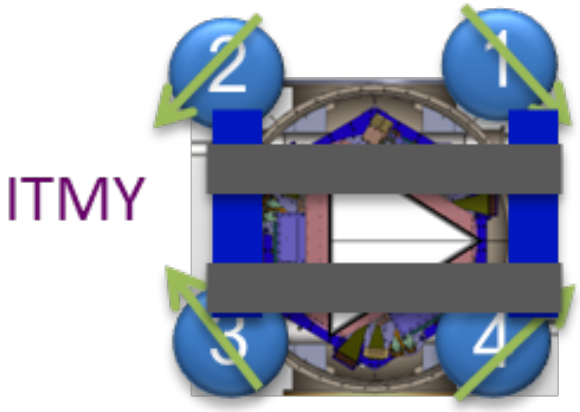
$$F_L = D^{-1}\, F_C$$

- Units are dimensionless $[\mathrm{N/N}]$ for the components of the first three lines of D^{-1}
- Units are $[\mathrm{m}]$ for the components of the last three lines of D^{-1}

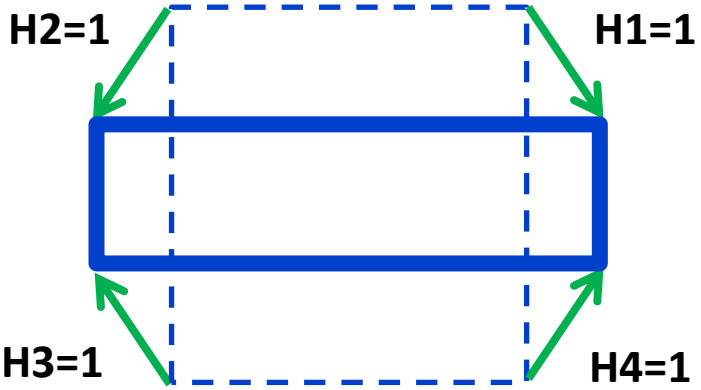
HEPI Horizontal Pringle Sensor Definition

- A unity horizontal “pringle” deformation is defined as a deformation that generates a unity displacement in each corner (H1 to H4).

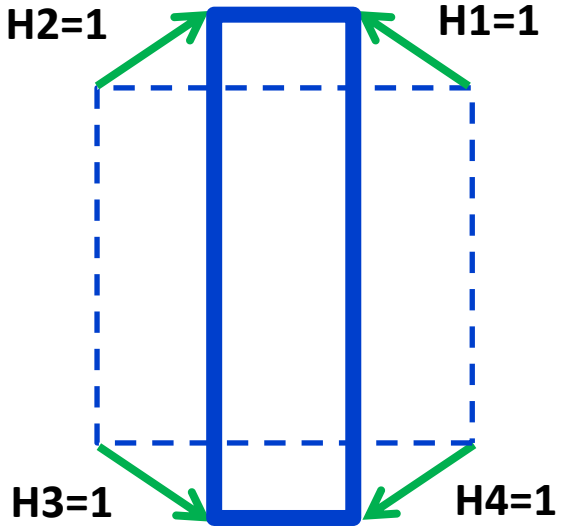
- In other words, a local displacement sensor reads a “positive 1 meter signal” for a “unity positive HP deformation”



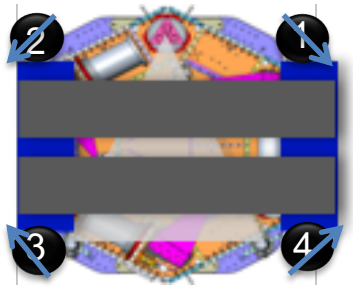
HP = +1



HP = +1

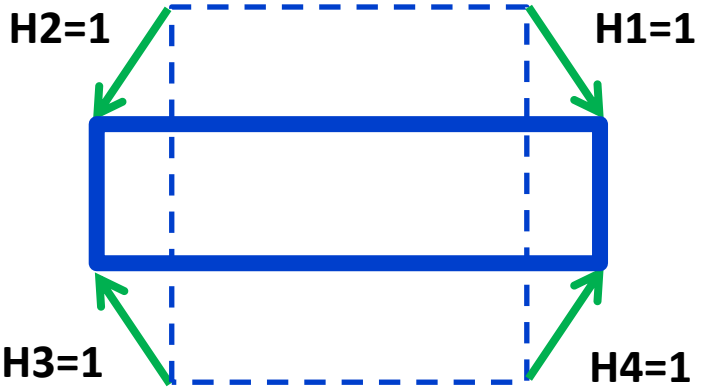


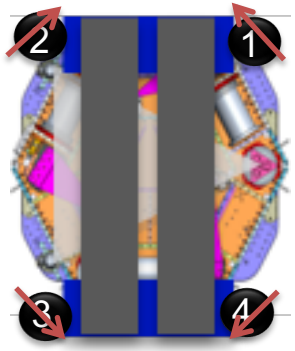
HEPI Horizontal Pringle Sensor Definition



HAM 2,3

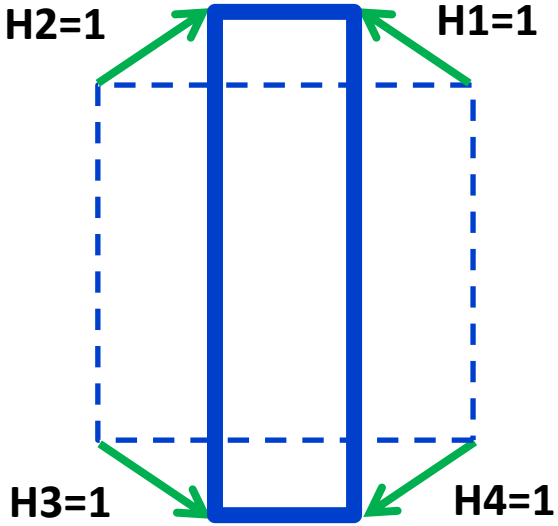
HP = +1





HAM4,5,6

HP = +1

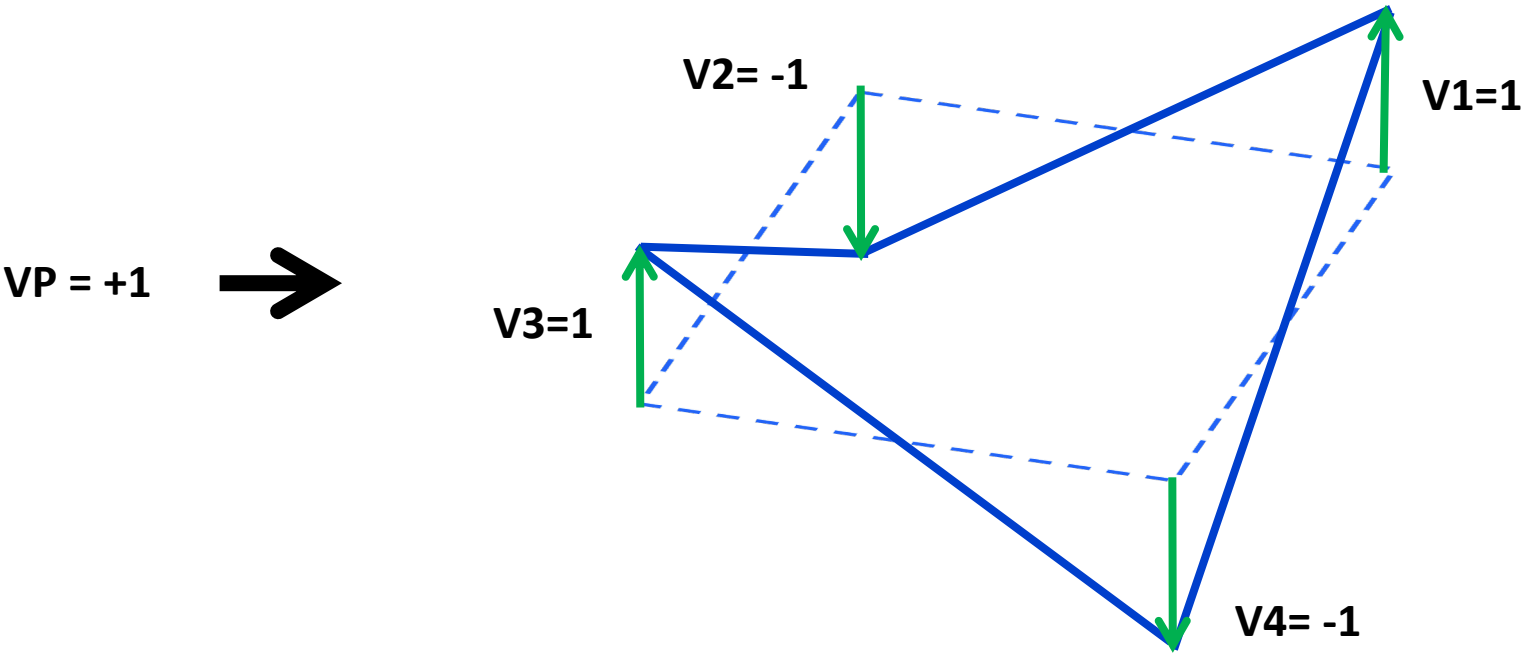


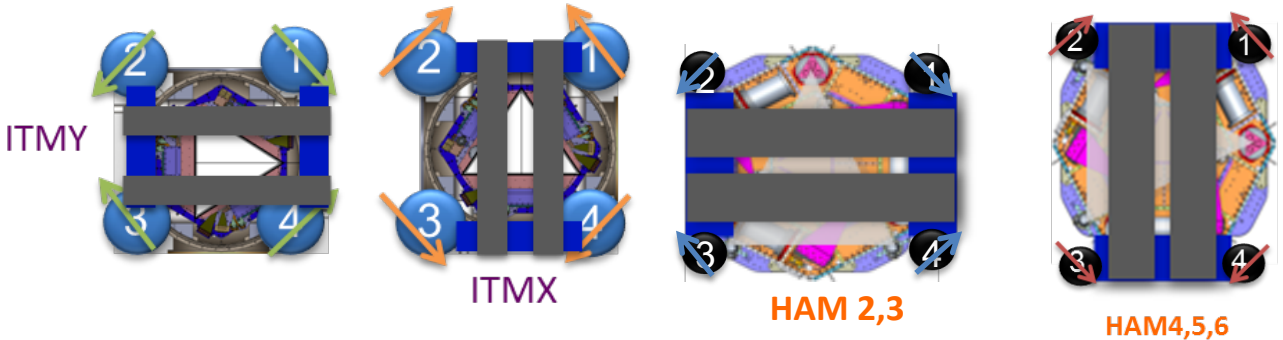
Note: A Positive HP always compress the blue beams and extend the support tubes.

Vertical Pringle Sensor Definition

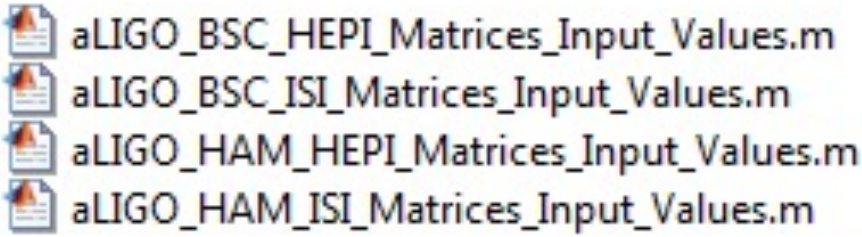
A unity Vertical "pringle" deformation is defined as a deformation that generates a displacement of 1 Meter in each sensor (V1=1 to V4).

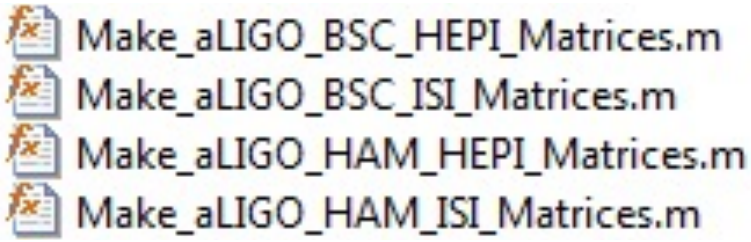
A positive VP deformation generates a positive V1 and V3 (negative V2 and V4)

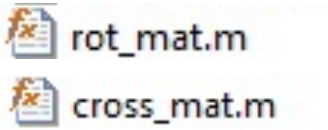




2.2) Scripts


aLIGO_BSC_HEPI_Matrices_Input_Values.m
aLIGO_BSC_ISI_Matrices_Input_Values.m
aLIGO_HAM_HEPI_Matrices_Input_Values.m
aLIGO_HAM_ISI_Matrices_Input_Values.m


Make_aLIGO_BSC_HEPI_Matrices.m
Make_aLIGO_BSC_ISI_Matrices.m
Make_aLIGO_HAM_HEPI_Matrices.m
Make_aLIGO_HAM_ISI_Matrices.m


rot_mat.m
cross_mat.m

aLIGO_HAM_ISI_Matrices_Input_Values.m

```
%% HAM-ISI INPUT VALUES
% This script calculates the HAM-ISI change of basis matrices
% Sensors Locations and directions are described in T1000388
clear
close all
clc

%% CPS HAM_4_5_6
% Corner 1 Locations and directions:
Loc_Hor1  = [0.53071; 0.66058; -0.42107+0.21749];
Dir_Hor1  = [cos(-pi/3); sin(-pi/3); 0];
Loc_Vert1 = [0.64703; -0.18553; -0.61151+0.21749];
Dir_Vert1 = [0; 0; 1];
% Local to Cartesian Sensor Matrix:
disp('HAM_4_5_6:')
CPS2CART = Make_aLIGO_HAM_ISI_Matrices(Loc_Hor1, Dir_Hor1, Loc_Vert1, Dir_Vert1,'Sens')

%% CPS HAM_2_3
% Corner 1 Locations and directions:
Loc_Hor1  = rot_mat(pi/2)*Loc_Hor1;
Dir_Hor1  = rot_mat(pi/2)*Dir_Hor1;
Loc_Vert1 = rot_mat(pi/2)*Loc_Vert1;
Dir_Vert1 = rot_mat(pi/2)*Dir_Vert1;
% Local to Cartesian Sensor Matrix:
disp('HAM_2_3:')
CPS2CART = Make_aLIGO_HAM_ISI_Matrices(Loc_Hor1, Dir_Hor1, Loc_Vert1, Dir_Vert1,'Sens')
```

```
71
72      %% Actuator HAM_4_5_6
73      % Corner 1 Locations and directions:
74 -    Loc_Hor1  = [0.52342; 0.64154; 0];
75 -    Dir_Hor1  = [cos(-pi/3); sin(-pi/3); 0];
76 -    Loc_Vert1 = [0.71120; 0; -0.59868+0.21749];
77 -    Dir_Vert1 = [0; 0; 1];
78      % Cartesian to Local Actuator Matrix:
79 -    disp('HAM_4_5_6:')
80 -    CART2ACT = Make_aLIGO_HAM_ISI_Matrices(Loc_Hor1, Dir_Hor1, Loc_Vert1, Dir_Vert1,'Actu')
81
82      %% Actuator  HAM_2_3
83      % Corner 1 Locations and directions:
84 -    Loc_Hor1  = rot_mat(pi/2)*Loc_Hor1;
85 -    Dir_Hor1  = rot_mat(pi/2)*Dir_Hor1;
86 -    Loc_Vert1 = rot_mat(pi/2)*Loc_Vert1;
87 -    Dir_Vert1 = rot_mat(pi/2)*Dir_Vert1;
88      % Cartesian to Local Actuator Matrix:
89 -    disp('HAM_2_3:')
90 -    CART2ACT = Make_aLIGO_HAM_ISI_Matrices(Loc_Hor1, Dir_Hor1, Loc_Vert1, Dir_Vert1,'Actu')
```

Make_aLIGO_HAM_ISI_Matrices

```
function Result=Make_aLIGO_HAM_ISI_Matrices(Loc_Hor1,Dir_Hor1,Loc_Vert1,Dir_Vert1,Type,Loc_Vert2,Loc_Vert3)

% Instruments Location in rows
Loc(:,1)=Loc_Hor1;                          % Horizontal Corner 1
Loc(:,2)=rot_mat(2*pi/3)*Loc_Hor1;          % Horizontal Corner 2
Loc(:,3)=rot_mat(4*pi/3)*Loc_Hor1;          % Horizontal Corner 3
Loc(:,4)=Loc_Vert1;                         % Vertical Corner 4
if Type == 'L4Cs'
    Loc(:,5)=Loc_Vert2;          % Vertical Corner 5
    Loc(:,6)=Loc_Vert3;          % Vertical Corner 6
    Type='Sens';
else
    Loc(:,5)=rot_mat(2*pi/3)*Loc_Vert1;          % Vertical Corner 5
    Loc(:,6)=rot_mat(4*pi/3)*Loc_Vert1;          % Vertical Corner 6
end


% Instruments Direction
Dir(:,1)=Dir_Hor1;                          % Horizontal Corner 1
Dir(:,2)=rot_mat(2*pi/3)*Dir_Hor1;          % Horizontal Corner 2
Dir(:,3)=rot_mat(4*pi/3)*Dir_Hor1;          % Horizontal Corner 3
Dir(:,4)=Dir_Vert1;                         % Vertical Corner 4
Dir(:,5)=rot_mat(2*pi/3)*Dir_Vert1;         % Vertical Corner 5
Dir(:,6)=rot_mat(4*pi/3)*Dir_Vert1;         % Vertical Corner 6
```

```
26 -  if Type == 'Sens'
27        % L=S*C (Local sensor as a function to Cartesian displacments):
28 -      for jj=1:6
29 -          S(jj,:)=Dir(:,jj)'*[eye(3) -cross_mat(Loc(:,jj))];
30 -      end
31        % Calculate the local to Cartesian matrix
32 -      L2C=S^-1;
33        % Swap Z and RZ
34 -      L2C_temp=L2C;
35 -      L2C(3,:)=L2C_temp(6,:);
36 -      L2C(4,:)=L2C_temp(3,:);
37 -      L2C(5,:)=L2C_temp(4,:);
38 -      L2C(6,:)=L2C_temp(5,:);
39 -      Result=round(L2C*1e6)*1e-6;
40 -  end
```

Projections from Cartesian to Local Motions

Inverting.

Re-ordering

Rounding

```
42 -  if Type == 'Actu'
43        % L=S*C (Local sensor as a function to Cartesian displacments):
44 -      for jj=1:6
45 -          D(:,jj)=[eye(3) ; cross_mat(Loc(:,jj))]*Dir(:,jj);
46 -      end
47        % Calculate the local to Cartesian matrix
48 -      C2L=D^-1;
49        % Swap Z and RZ
50 -      C2L_temp=C2L;
51 -      C2L(:,3)=C2L_temp(:,6);
52 -      C2L(:,4)=C2L_temp(:,3);
53 -      C2L(:,5)=C2L_temp(:,4);
54 -      C2L(:,6)=C2L_temp(:,5);
55 -      Result=round(C2L*1e6)*1e-6;
56 -  end
```

2.3) Output Names

Current Outputs

```
>> load('aLIGO_HAM_ISI_Matrices_X_Direction.mat')
>> whos
  Name            Size              Bytes  Class     Attributes

  CART2ACT        6x6                 288  double
  CPS2CART        6x6                 288  double
  CPSALIGN        6x6                 288  double
  GS132CART       6x6                 288  double
  L4C2CART        6x6                 288  double
```

make_ham_hepi_modal_matrixs(2)

```
ans =

    L4C: [8x8 double]
    IPS: [8x8 double]
Act_L2M: [8x8 double]
Act_M2L: [8x8 double]
```

The standard version will use the MEDM channel names

Add DCC #, date, and name of mfile used to create the matrices

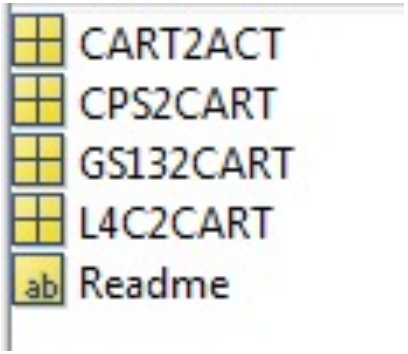
3) Matrices values

3.1) HAM-ISI Matrices

seismic - Revision 7887: /HAM-ISI/Common/Basis_Change_Matrices

- ..
- Archives/ ⟶ Old programs and matrices
- Make_aLIGO_HAM_ISI_Matrices.m ⟶ Matrix calculation program
- aLIGO_HAM_ISI_2_3.mat ⟶ Output Data
- aLIGO_HAM_ISI_4_5_6.mat ⟶ Output Data
- aLIGO_HAM_ISI_Matrices_Input_Values.m ⟶ Input Values/Top level script

>> load aLIGO_HAM_ISI_4_5_6.mat

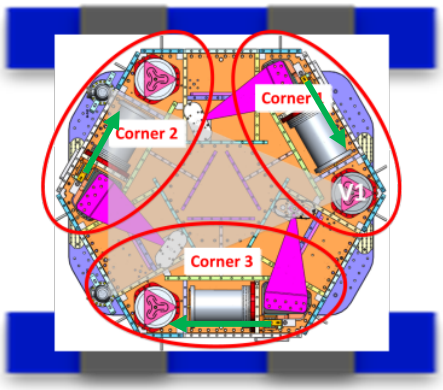



```
>> Readme

Readme =

These matrices were generated and saved on 19-Dec-2013 using aLIGO_HAM_ISI_Matrices.m

See T1000388 for more details.
```

Note: Old matrices have been saved in /seismic/HAM-ISI/Common/Basis_Change_Matrices/Archives

HAM-ISI CPS

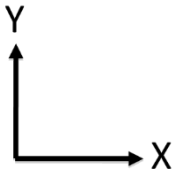
HAM 4,5,6



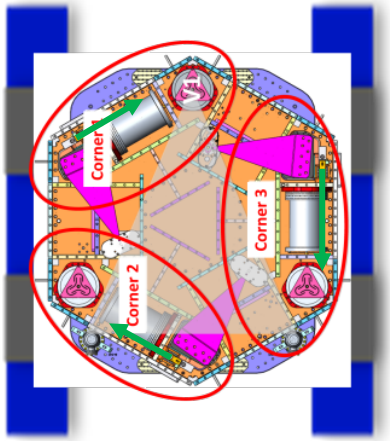
HAM_4_5_6:

CPS2CART =

0.3333	0.3333	-0.6667	-0.1938	0.0488	0.1450
-0.5773	0.5773	0	0.0556	-0.1956	0.1401
-0.4220	-0.4220	-0.4220	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.2730	0.9610	-0.6880
0	0	0	-0.9521	0.2396	0.7125



HAM 2,3



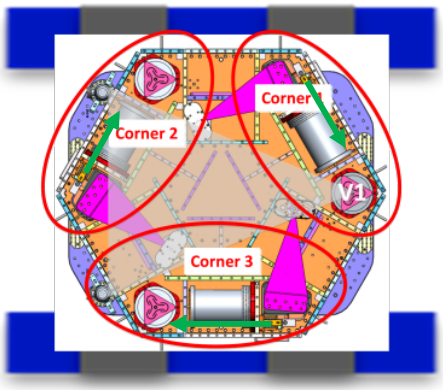
HAM_2_3:

CPS2CART =

0.5773	-0.5773	0	-0.0556	0.1956	-0.1401
0.3333	0.3333	-0.6667	-0.1938	0.0488	0.1450
-0.4220	-0.4220	-0.4220	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	0.9521	-0.2396	-0.7125
0	0	0	-0.2730	0.9610	-0.6880

HAM-ISI GS13

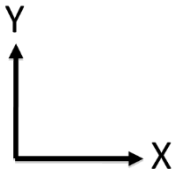
HAM 4,5,6



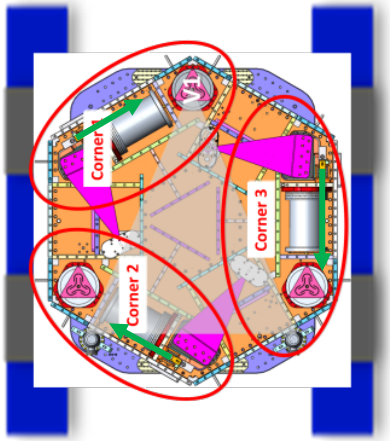
HAM_4_5_6:

GS132CART =

0.3333	0.3333	-0.6667	-0.0282	0.0141	0.0141
-0.5773	0.5773	0	0	-0.0244	0.0244
-0.4906	-0.4906	-0.4906	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	0	0.7332	-0.7332
0	0	0	-0.8467	0.4233	0.4233



HAM 2,3



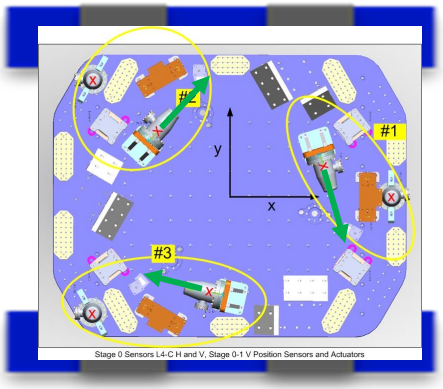
HAM_2_3:

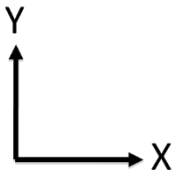
GS132CART =

0.5773	-0.5773	0	0	0.0244	-0.0244
0.3333	0.3333	-0.6667	-0.0282	0.0141	0.0141
-0.4906	-0.4906	-0.4906	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	0.8467	-0.4233	-0.4233
0	0	0	0	0.7332	-0.7332

HAM-ISI L4Cs

HAM 4,5,6





HAM_4_5_6:

L4C2CART =

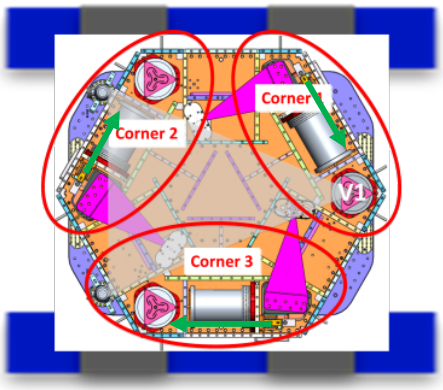
0.2005	0.4504	-0.6509	-0.2590	0.1295	0.1295
-0.6358	0.4915	0.1443	0	-0.3319	0.3319
-0.6562	-0.6562	-0.6562	0	0	0
0	0	0	0.4600	0.2700	0.2700
0	0	0	0	0.8288	-0.8288
0	0	0	-0.6467	0.3234	0.3234

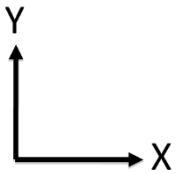
Need to Check L4C Signs

No Stage 0 L4Cs on HAM 2&3

HAM-ISI Actuators

HAM 4,5,6



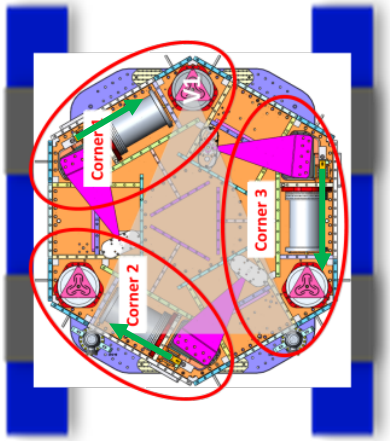


HAM_4_5_6:

CART2ACT =

0.3333	-0.5773	-0.4306	0	0	0
0.3333	0.5773	-0.4306	0	0	0
-0.6667	0	-0.4306	0	0	0
0	0	0	0.3333	0	-0.9374
0	0	0	0.3333	0.8118	0.4687
0	0	0	0.3333	-0.8118	0.4687

HAM 2,3



HAM_2_3:

CART2ACT =

0.5773	0.3333	-0.4306	0	0	0
-0.5773	0.3333	-0.4306	0	0	0
0	-0.6667	-0.4306	0	0	0
0	0	0	0.3333	0.9374	0
0	0	0	0.3333	-0.4687	0.8118
0	0	0	0.3333	-0.4687	-0.8118

3.2) BSC-HEPI Matrices

seismic - Revision 7891: /HEPI/Common/Basis_Change_Matrices_HEPI/BSC

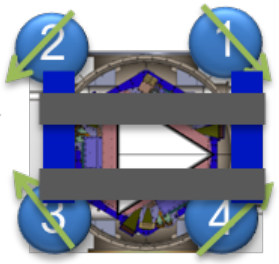
- ..
- Make_aLIGO_BSC_HEPI_Matrices.m → **Matrix calculation program**
- aLIGO_BSC_HEPI_BS_ITMY_ETMX.mat → **Output Data**
- aLIGO_BSC_HEPI_ITMX_ETMY.mat → **Output Data**
- aLIGO_BSC_HEPI_Matrices_Input_Values.m → **Input Values/Top level script**

BSC-HEPI IPS

BSC_ISI_BS_ITMY_ETMX:

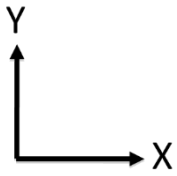
HEPI not ISI

IPS2CART =



ITMY

0.3536	-0.3536	-0.3536	0.3536	0	0	0	0
-0.3536	-0.3536	0.3536	0.3536	0	0	0	0
-0.1221	0.1221	-0.1221	0.1221	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.1730	0.1730	-0.1730	-0.1730
0	0	0	0	-0.1730	0.1730	0.1730	-0.1730
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500



BSC_ISI_ITMX_ETMY:

IPS2CART =

ITMX

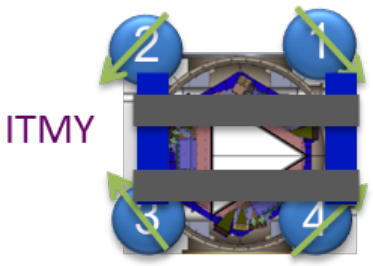
-0.3536	0.3536	0.3536	-0.3536	0	0	0	0
0.3536	0.3536	-0.3536	-0.3536	0	0	0	0
0.1221	-0.1221	0.1221	-0.1221	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.1730	0.1730	-0.1730	-0.1730
0	0	0	0	-0.1730	0.1730	0.1730	-0.1730
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500

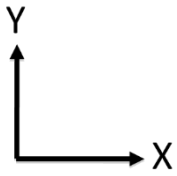
BSC-HEPI L4C

BSC_ISI_BS_ITMY_ETMX:

L4C2CART =

0.3536	-0.3536	-0.3536	0.3536	0	0	0	0
-0.3536	-0.3536	0.3536	0.3536	0	0	0	0
-0.1221	0.1221	-0.1221	0.1221	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.1730	0.1730	-0.1730	-0.1730
0	0	0	0	-0.1730	0.1730	0.1730	-0.1730
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500

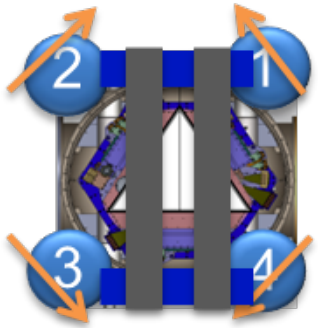




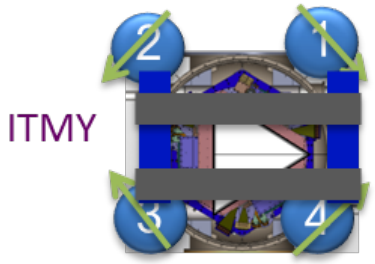
BSC_ISI_ITMX_ETMY:

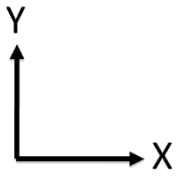
L4C2CART =

-0.3536	0.3536	0.3536	-0.3536	0	0	0	0
0.3536	0.3536	-0.3536	-0.3536	0	0	0	0
0.1221	-0.1221	0.1221	-0.1221	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.1730	0.1730	-0.1730	-0.1730
0	0	0	0	-0.1730	0.1730	0.1730	-0.1730
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500



BSC-HEPI Actuators





BSC_ISI_BS_ITMY_ETMX:

CART2ACT =

0.3536	-0.3536	-0.1221	0.2500	0	0	0	0
-0.3536	-0.3536	0.1221	0.2500	0	0	0	0
-0.3536	0.3536	-0.1221	0.2500	0	0	0	0
0.3536	0.3536	0.1221	0.2500	0	0	0	0
0	0	0	0	0.2500	0.1730	-0.1730	0.2500
0	0	0	0	0.2500	0.1730	0.1730	-0.2500
0	0	0	0	0.2500	-0.1730	0.1730	0.2500
0	0	0	0	0.2500	-0.1730	-0.1730	-0.2500

BSC_ISI_ITMX_ETMY:

CART2ACT =

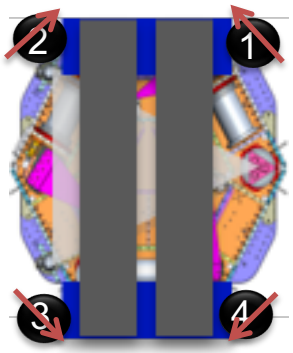
-0.3536	0.3536	0.1221	0.2500	0	0	0	0
0.3536	0.3536	-0.1221	0.2500	0	0	0	0
0.3536	-0.3536	0.1221	0.2500	0	0	0	0
-0.3536	-0.3536	-0.1221	0.2500	0	0	0	0
0	0	0	0	0.2500	0.1730	-0.1730	0.2500
0	0	0	0	0.2500	0.1730	0.1730	-0.2500
0	0	0	0	0.2500	-0.1730	0.1730	0.2500
0	0	0	0	0.2500	-0.1730	-0.1730	-0.2500

3.3) HAM-HEPI Matrices

seismic - Revision 7891: /HEPI/Common/Basis_Change_Matrices_HEPI/HAM

- ..
- Make_aLIGO_HAM_HEPI_Matrices.m ⟶ **Matrix calculation program**
- aLIGO_HAM_HEPI_1_2_3.mat ⟶ **Output Data**
- aLIGO_HAM_HEPI_4_5_6.mat ⟶ **Output Data**
- aLIGO_HAM_HEPI_Matrices_Input_Values.m ⟶ **Input Values/Top level script**

BSC-HEPI IPS

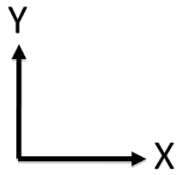


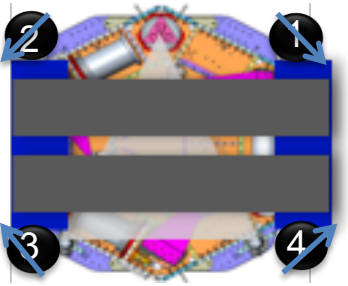
HAM4,5,6

HAM_4_5_6:

IPS2CART =

-0.5157	0.5157	0.5157	-0.5157	0	0	0	0
0.2858	0.2858	-0.2858	-0.2858	0	0	0	0
0.1406	-0.1406	0.1406	-0.1406	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.2894	0.2894	-0.2894	-0.2894
0	0	0	0	-0.1609	0.1609	0.1609	-0.1609
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500





HAM 2,3

HAM_1_2_3:

IPS2CART =

0.2858	-0.2858	-0.2858	0.2858	0	0	0	0
-0.5157	-0.5157	0.5157	0.5157	0	0	0	0
-0.1406	0.1406	-0.1406	0.1406	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.1609	0.1609	-0.1609	-0.1609
0	0	0	0	-0.2894	0.2894	0.2894	-0.2894
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500

HAM-HEPI

L4C

HAM 4,5,6

aLIGO_HAM_HEPI_4_5_6.mat

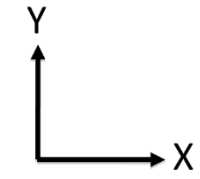
```
HAM_4_5_6:

L4C2CART =
```

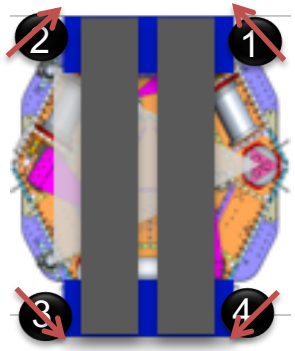
-0.5157	0.5157	0.5157	-0.5157	0	0	0	0
0.2858	0.2858	-0.2858	-0.2858	0	0	0	0
0.1406	-0.1406	0.1406	-0.1406	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.2894	0.2894	-0.2894	-0.2894
0	0	0	0	-0.1609	0.1609	0.1609	-0.1609
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500

make_ham_hepi_modal_matrixs(2)

```
>> ans.L4C

ans =
```

-0.5157	0.5157	0.5157	-0.5157	0	0	0	0
0.2858	0.2858	-0.2858	-0.2858	0	0	0	0
0.1406	-0.1406	0.1406	-0.1406	0	0	0	0
0.2500	0.2500	0.2500	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2500	0.2500	0.2500
0	0	0	0	0.2848	0.2848	-0.2848	-0.2848
0	0	0	0	-0.1617	0.1617	0.1617	-0.1617
0	0	0	0	0.2500	-0.2500	0.2500	-0.2500





HAM4,5,6

HAM-HEPI

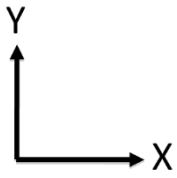
L4C

HAM 2,3

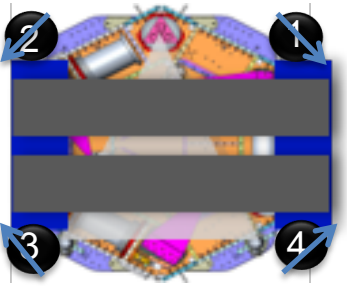
aLIGO_HAM_HEPI_1_2_3.mat

```
HAM_1_2_3:

L4C2CART =

    0.2858   -0.2858   -0.2858    0.2858         0         0         0         0
   -0.5157   -0.5157    0.5157    0.5157         0         0         0         0
   -0.1406    0.1406   -0.1406    0.1406         0         0         0         0
    0.2500    0.2500    0.2500    0.2500         0         0         0         0
         0         0         0         0    0.2500    0.2500    0.2500    0.2500
         0         0         0         0    0.1609    0.1609   -0.1609   -0.1609
         0         0         0         0   -0.2894    0.2894    0.2894   -0.2894
         0         0         0         0    0.2500   -0.2500    0.2500   -0.2500
```

make_ham_hepi_modal_matrixs(1)




```
>> ans.L4C

ans =

    0.2858   -0.2858   -0.2858    0.2858         0         0         0         0
   -0.5157   -0.5157    0.5157    0.5157         0         0         0         0
    0.2697   -0.2697    0.2697   -0.2697         0         0         0         0
    0.2500    0.2500    0.2500    0.2500         0         0         0         0
         0         0         0         0    0.2500    0.2500    0.2500    0.2500
         0         0         0         0    0.1617    0.1617   -0.1617   -0.1617
         0         0         0         0   -0.2848    0.2848    0.2848   -0.2848
         0         0         0         0    0.2500   -0.2500    0.2500   -0.2500
```



HAM 2,3

HAM-HEPI

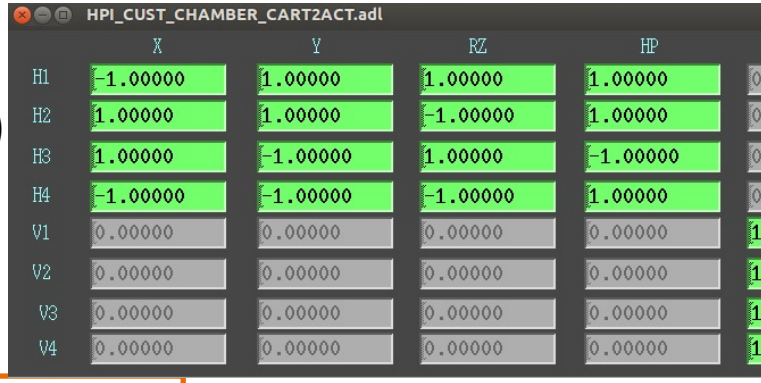
ACT

HAM4,5,6

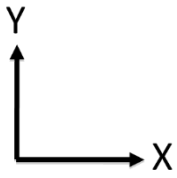
aLIGO_HAM_HEPI_4_5_6.mat

```
HAM_4_5_6:

CART2ACT =
```

-0.5157	0.2858	0.1406	0.2500	0	0	0	0
0.5157	0.2858	-0.1406	0.2500	0	0	0	0
0.5157	-0.2858	0.1406	0.2500	0	0	0	0
-0.5157	-0.2858	-0.1406	0.2500	0	0	0	0
0	0	0	0	0.2500	0.2894	-0.1609	0.2500
0	0	0	0	0.2500	0.2894	0.1609	-0.2500
0	0	0	0	0.2500	-0.2894	0.1609	0.2500
0	0	0	0	0.2500	-0.2894	-0.1609	-0.2500

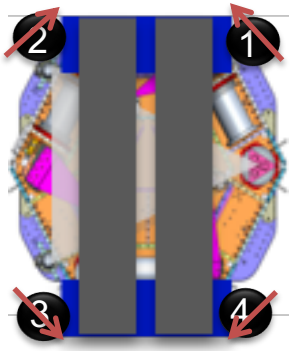


make_ham_hepi_modal_matrixs(2)




```
>> ans.Act_M2L

ans =
```

-1	1	1	-1	0	0	0	0
1	1	-1	-1	0	0	0	0
1	-1	1	-1	0	0	0	0
1	1	1	1	0	0	0	0
0	0	0	0	1	1	1	1
0	0	0	0	1	1	-1	-1
0	0	0	0	-1	1	1	-1
0	0	0	0	1	-1	1	-1



HAM4,5,6

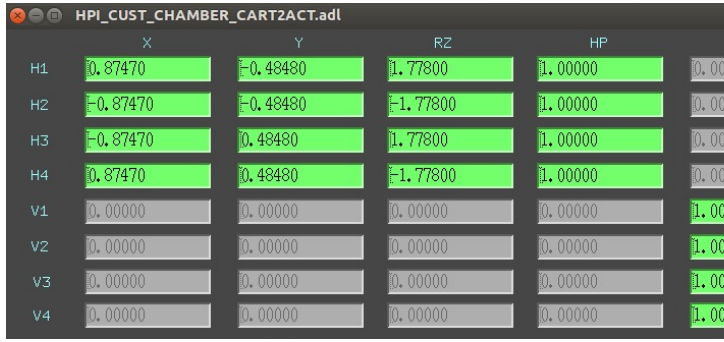
HAM-HEPI

ACT

HAM 2,3

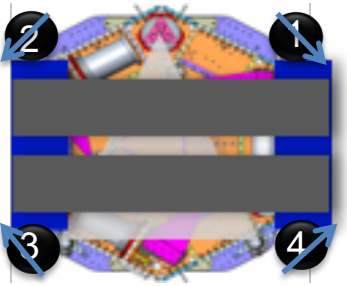
aLIGO_HAM_HEPI_1_2_3.mat

```
HAM_1_2_3:

CART2ACT =

    0.2858   -0.5157   -0.1406    0.2500         0         0         0         0
   -0.2858   -0.5157    0.1406    0.2500         0         0         0         0
   -0.2858    0.5157   -0.1406    0.2500         0         0         0         0
    0.2858    0.5157    0.1406    0.2500         0         0         0         0
         0         0         0         0    0.2500    0.1609   -0.2894    0.2500
         0         0         0         0    0.2500    0.1609    0.2894   -0.2500
         0         0         0         0    0.2500   -0.1609    0.2894    0.2500
         0         0         0         0    0.2500   -0.1609   -0.2894   -0.2500
```



make_ham_hepi_modal_matrixs(1)

```
>> ans.Act_M2L

ans =

     1    -1    -1     1     0     0     0     0
    -1    -1     1     1     0     0     0     0
    -1     1    -1     1     0     0     0     0
     1     1     1     1     0     0     0     0
     0     0     0     0     1     1     1     1
     0     0     0     0     1     1    -1    -1
     0     0     0     0    -1     1     1    -1
     0     0     0     0     1    -1     1    -1
```

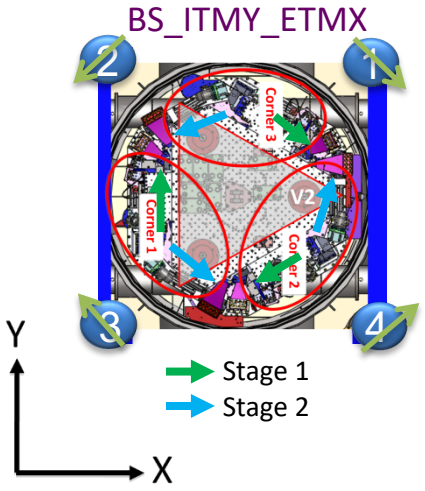


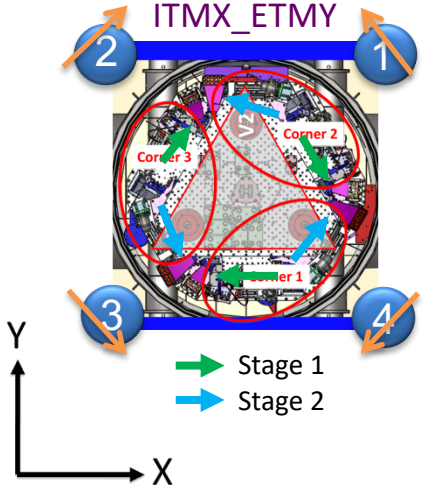
HAM 2,3

3.4) BSC-ISI Matrices

/seismic/BSC-ISI/Common/Basis_Change_BSC_ISI/aLIGO/Matrices/

- aLIGO_BSC_ISI_Matrices_Direction_X.mat
- aLIGO_BSC_ISI_Matrices_Direction_Y.mat
- aLIGO_BSC_ISI_Matrices_Y_Direction.mat
- aLIGO_BSC_ISI_Matrices_Y_Direction_2011_10_01.mat

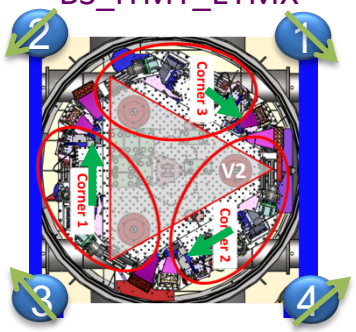




BSC-ISI

Stage 1 CPS

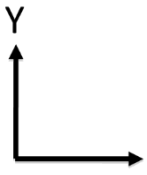
BS_ITMY_ETMX



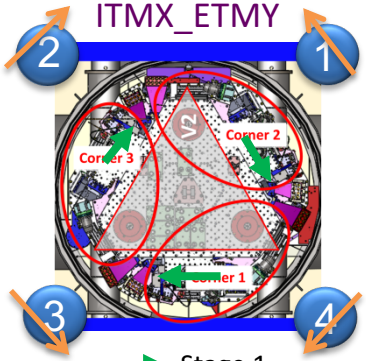
BS_ITMY_ETMX:

ST1_CPS2CART =

0	-0.5773	0.5773	-0.0361	0.0305	0.0056
0.6667	-0.3333	-0.3333	-0.0144	-0.0240	0.0384
-0.3467	-0.3467	-0.3467	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.2389	-0.3984	0.6373
0	0	0	0.5980	-0.5059	-0.0921



ITMX_ETMY



ITMX_ETMY:

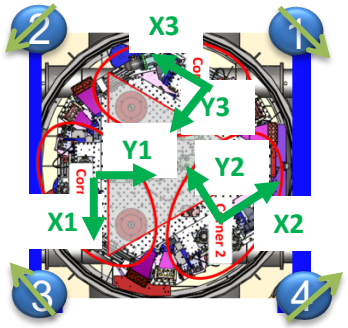
ST1_CPS2CART =

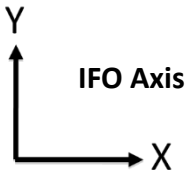
-0.6667	0.3333	0.3333	0.0144	0.0240	-0.0384
0	-0.5773	0.5773	-0.0361	0.0305	0.0056
-0.3467	-0.3467	-0.3467	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.5980	0.5059	0.0921
0	0	0	-0.2389	-0.3984	0.6373

BSC-ISI

Stage 1 T240

BS_ITMY_ETMX





Cartesian to Local Test to check the sign Y1, Y2,Y3?

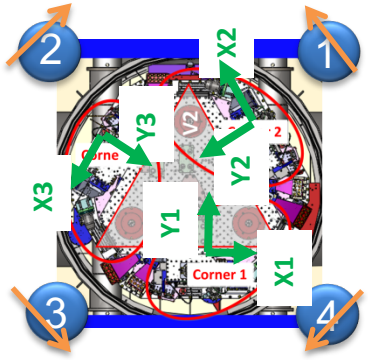
ST1_T2402CART =

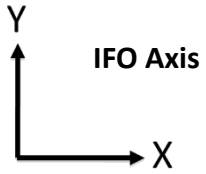
	X1	Y1	Z1	X2	Y2	Z2	X3	Y3	Z3
X	0	0.3333	-0.1353	0.2887	-0.1667	0.0677	-0.2887	-0.1667	0.0677
Y	-0.3333	0	0	0.1667	0.2887	-0.1172	0.1667	-0.2887	0.1172
RZ	0.5834	0	0	0.5834	0	0	0.5834	0	0
Z	0	0	0.3333	0	0	0.3333	0	0	0.3333
RX	0	0	0	0	0	-1.0104	0	0	1.0104
RY	0	0	1.1667	0	0	-0.5834	0	0	-0.5834

BSC-ISI

Stage 1 T240

ITMX_ETMY





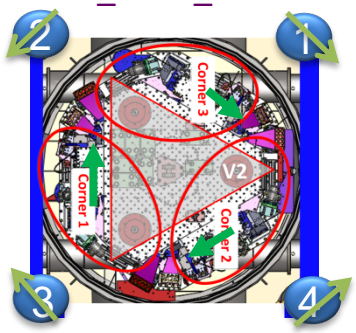
ST1_T2402CART =

	X1	Y1	Z1	X2	Y2	Z2	X3	Y3	Z3
X	0.3333	0	0	-0.1667	-0.2887	0.1172	-0.1667	0.2887	-0.1172
Y	0	0.3333	-0.1353	0.2887	-0.1667	0.0677	-0.2887	-0.1667	0.0677
RZ	0.5834	0	0	0.5834	0	0	0.5834	0	0
Z	0	0	0.3333	0	0	0.3333	0	0	0.3333
RX	0	0	-1.1667	0	0	0.5834	0	0	0.5834
RY	0	0	0	0	0	-1.0104	0	0	1.0104

BSC-ISI

Stage 1 L4C

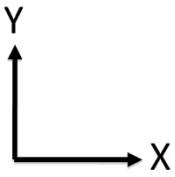
BS_ITMY_ETMX



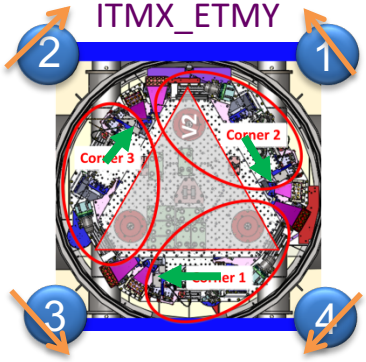
BS_ITMY_ETMX:

ST1_L4C2CART =

0	-0.5773	0.5773	-0.0516	0.0258	0.0258
0.6667	-0.3333	-0.3333	0	-0.0447	0.0447
-0.4233	-0.4233	-0.4233	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	0	-0.7026	0.7026
0	0	0	0.8113	-0.4057	-0.4057



ITMX_ETMY



ITMX_ETMY:

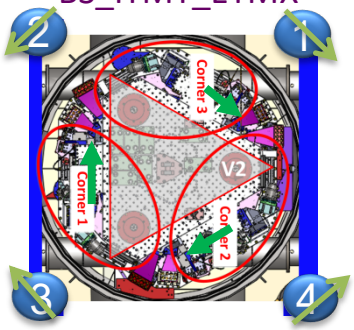
ST1_L4C2CART =

-0.6667	0.3333	0.3333	0	0.0447	-0.0447
0	-0.5773	0.5773	-0.0516	0.0258	0.0258
-0.4233	-0.4233	-0.4233	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.8113	0.4057	0.4057
0	0	0	0	-0.7026	0.7026

BSC-ISI

Stage 1 Actuator

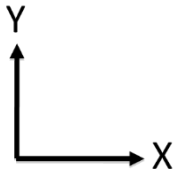
BS_ITMY_ETMX



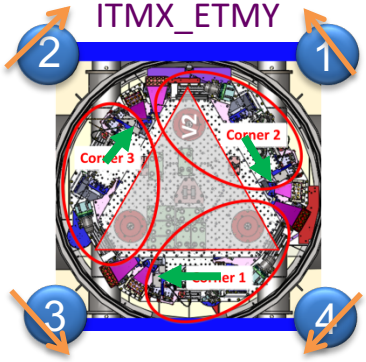
BS_ITMY_ETMX:

ST1_CART2ACT =

0	0.6667	-0.4057	0	0	0
-0.5773	-0.3333	-0.4057	0	0	0
0.5773	-0.3333	-0.4057	0	0	0
0	0	0	0.3333	-0.2767	0.7023
0	0	0	0.3333	-0.4699	-0.5908
0	0	0	0.3333	0.7466	-0.1116



ITMX_ETMY



ITMX_ETMY:

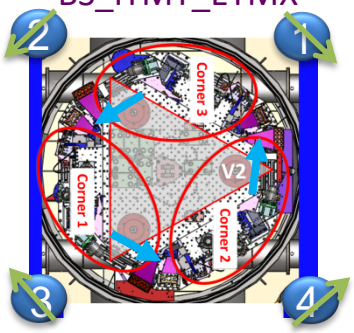
ST1_CART2ACT =

-0.6667	0	-0.4057	0	0	0
0.3333	-0.5773	-0.4057	0	0	0
0.3333	0.5773	-0.4057	0	0	0
0	0	0	0.3333	-0.7023	-0.2767
0	0	0	0.3333	0.5908	-0.4699
0	0	0	0.3333	0.1116	0.7466

BSC-ISI

Stage 2 CPS

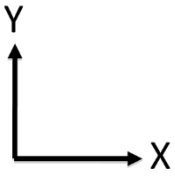
BS_ITMY_ETMX



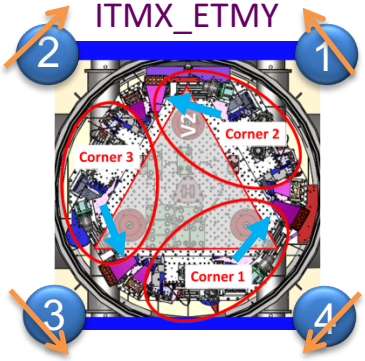
BS_ITMY_ETMX:

ST2_CPS2CART =

0.5773	0	-0.5773	-0.0602	0.0613	-0.0012
-0.3333	0.6667	-0.3333	-0.0361	-0.0340	0.0701
0.4821	0.4821	0.4821	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.5057	-0.4767	0.9825
0	0	0	0.8425	-0.8592	0.0168



ITMX_ETMY



ITMX_ETMY:

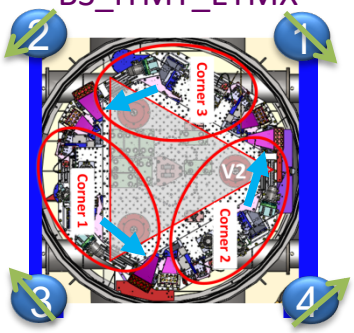
ST2_CPS2CART =

0.3333	-0.6667	0.3333	0.0361	0.0340	-0.0701
0.5773	0	-0.5773	-0.0602	0.0613	-0.0012
0.4821	0.4821	0.4821	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.8425	0.8592	-0.0168
0	0	0	-0.5057	-0.4767	0.9825

BSC-ISI

Stage 2 GS13

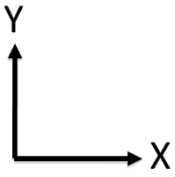
BS_ITMY_ETMX



BS_ITMY_ETMX:

ST2_GS132CART =

0.5773	0	-0.5773	-0.0210	0.0420	-0.0210
-0.3333	0.6667	-0.3333	-0.0364	-0.0000	0.0364
0.4374	0.4374	0.4374	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.8419	-0.0000	0.8419
0	0	0	0.4861	-0.9721	0.4860

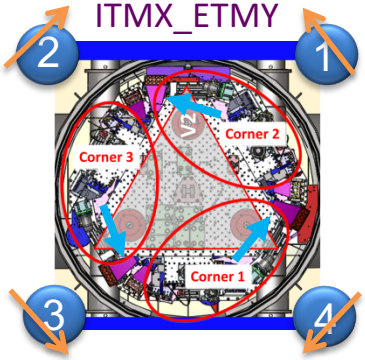


ITMX_ETMY:

ST2_GS132CART =

0.3333	-0.6667	0.3333	0.0364	0.0000	-0.0364
0.5773	0	-0.5773	-0.0210	0.0420	-0.0210
0.4374	0.4374	0.4374	0	0	0
0	0	0	0.3333	0.3333	0.3333
0	0	0	-0.4861	0.9721	-0.4860
0	0	0	-0.8419	-0.0000	0.8419

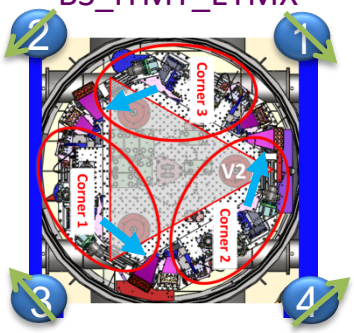
ITMX_ETMY



BSC-ISI

Stage 2 Actuator

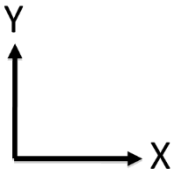
BS_ITMY_ETMX



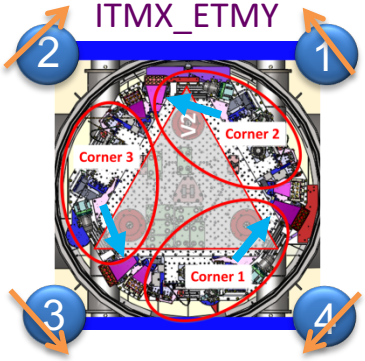
BS_ITMY_ETMX:

ST2_CART2ACT =

0.5773	-0.3333	0.5712	0	0	0
0	0.6667	0.5712	0	0	0
-0.5773	-0.3333	0.5712	0	0	0
0	0	0	0.3333	-0.6293	0.8253
0	0	0	0.3333	-0.4001	-0.9576
0	0	0	0.3333	1.0294	0.1324



ITMX_ETMY



ITMX_ETMY:

ST2_CART2ACT =

0.3333	0.5773	0.5712	0	0	0
-0.6667	0	0.5712	0	0	0
0.3333	-0.5773	0.5712	0	0	0
0	0	0	0.3333	-0.8253	-0.6293
0	0	0	0.3333	0.9576	-0.4001
0	0	0	0.3333	-0.1324	1.0294

Appendix 1: Translation between new and former naming convention

The old convention ("X direction", "Y direction" naming) is now obsolete and should not ne used anywhere anymore

HAM-ISI in HAM 4, 5 and 6 used to be labeled "X direction" (because V1 GS13 points toward the X axis). The mat files containing their matrices are now labeled "HAM_ISI_4_5_6 " for clarity.

HAM-ISI in HAM 2 and 3 used to be labeled "Y direction" (because V1 GS13 points toward the X axis). The mat files containing their matrices are now labeled "HAM_ISI_2_3 " for clarity.

HAM-HEPI in HAM 4, 5 and 6 used to be labeled "Y direction" (because these chambers are aligned with the Y axis). The mat files containing their matrices are now labeled "HAM_HEPI_4_5_6 " for clarity.

HAM-HEPI in HAM 2 and 3 used to be labeled "X direction" (because these chambers are aligned with the X axis). The mat files containing their matrices are now labeled "HAM_ISI_2_3 " for clarity.

BSC-ISI in BS, ITMY and ETMX used to be labeled "X direction" (because V2 GS13 points toward the X axis). The mat files containing their matrices are now labeled "BSC_ISI_BS_ITMY_ETMX " for clarity.

BSC-ISI in ITMX and ETMY used to be labeled "Y direction" (because V1 GS13 points toward the X axis). The mat files containing their matrices are now labeled "BSC_ISI_ITMX_ETMY" for clarity.

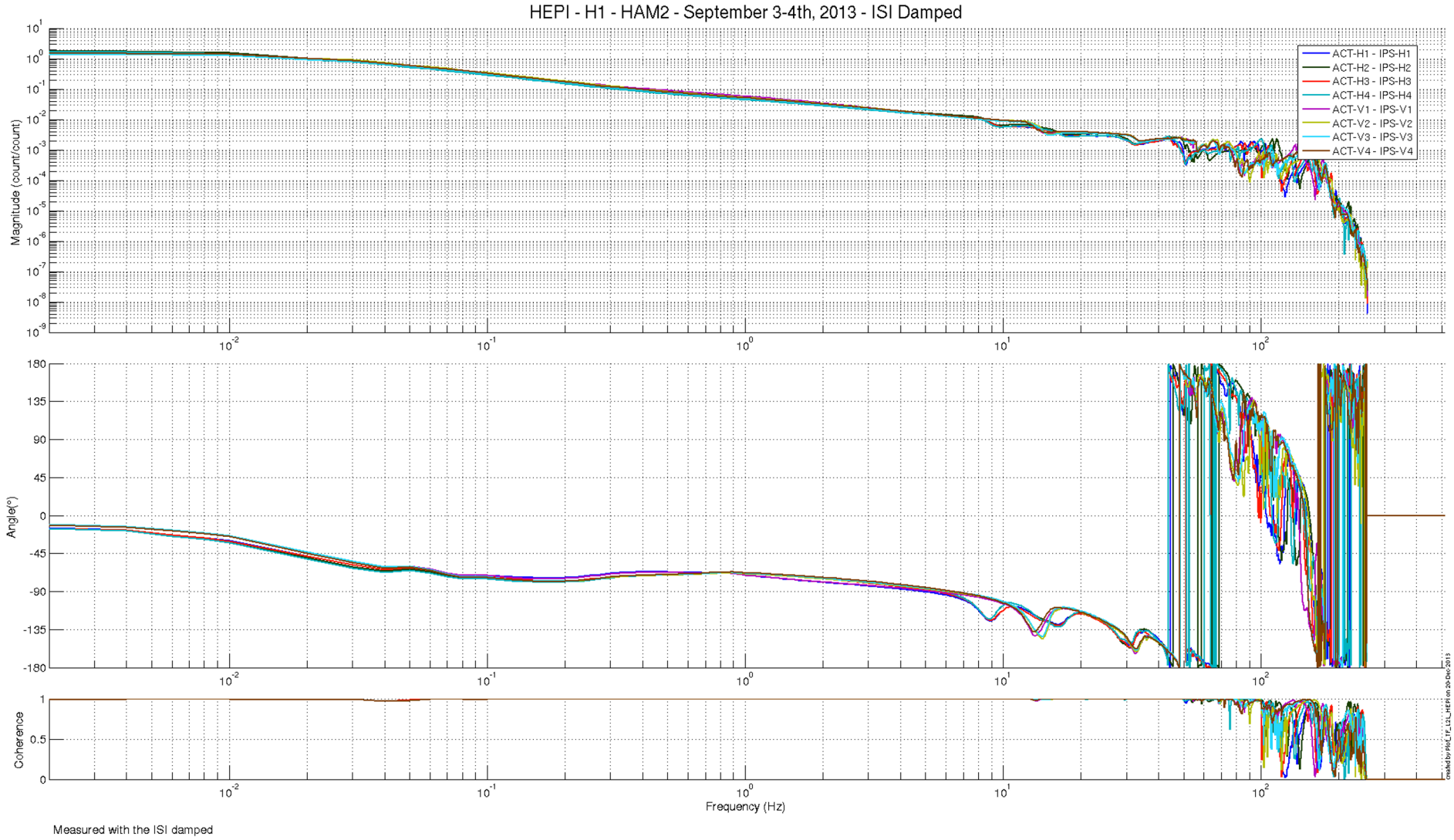
BSC-HEPI in BS, ITMY and ETMX used to be labeled "Y direction" (because these chambers are aligned with the Y axis). The mat files containing their matrices are now labeled "BSC_HEPI_BS_ITMY_ETMX " for clarity.

BSC-HEPI in ITMX and ETMY used to be labeled "X direction" (because these chambers are aligned with the X axis). The mat files containing their matrices are now labeled "BSC_HEPI_ITMX_ETMY " for clarity.

Appendix 2:

Example of Transfer Functions to establish instrument signs to be applied in symetrization filters.

HAM-HEPI IPS transfer functions*: **- Actuators and IPS are in phase in this example.**
No sign correction necessary in the output symmetrization filters

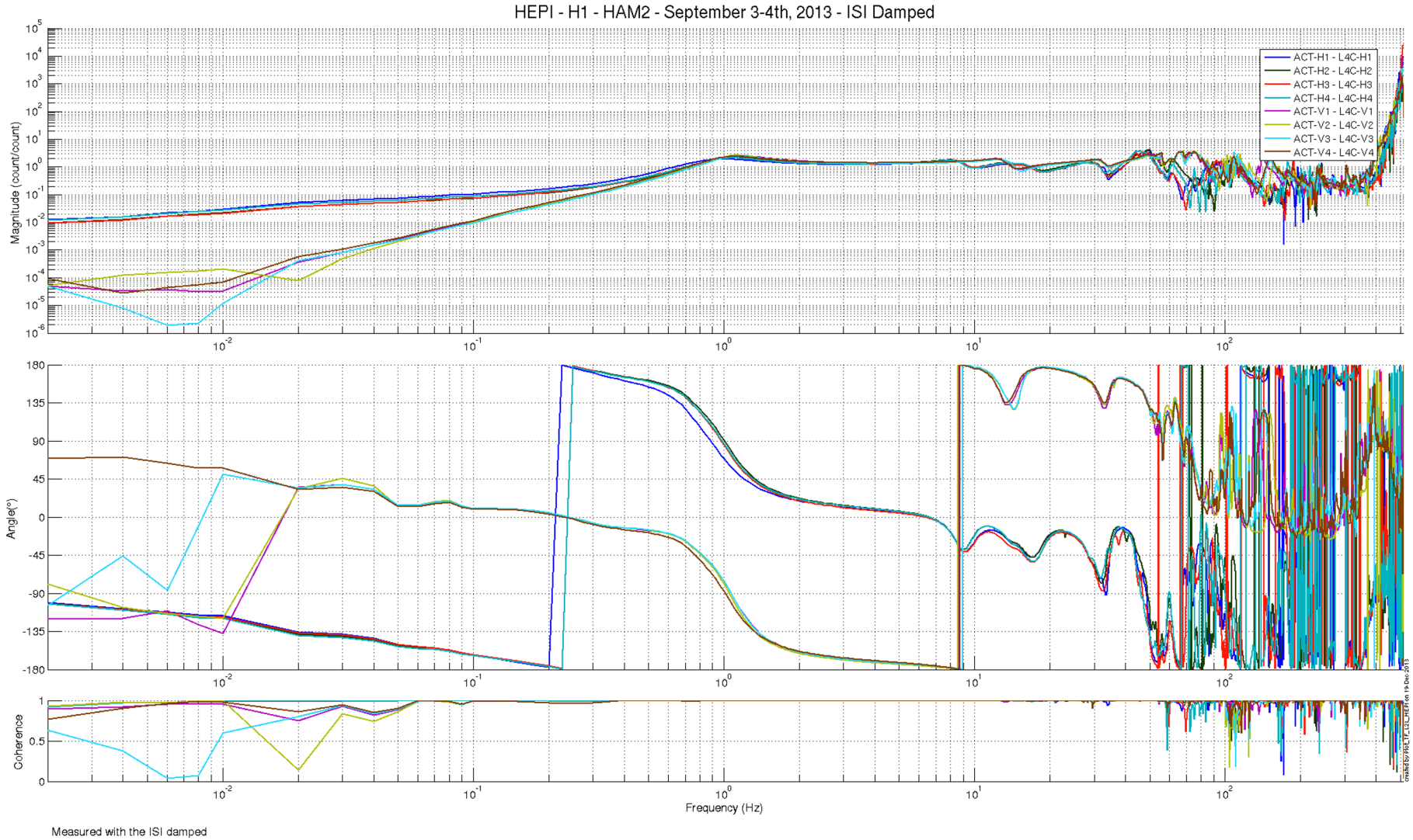


*** Local to local transfer function: from local actuator "Exc channel" to "IN1 channel" in the local sensor input filter's. Only the "Comp filter" must be engaged in the actuator bank (to partially revert the coil driver and actuator frequency response).**

HAM-HEPI L4Cs transfer functions*:

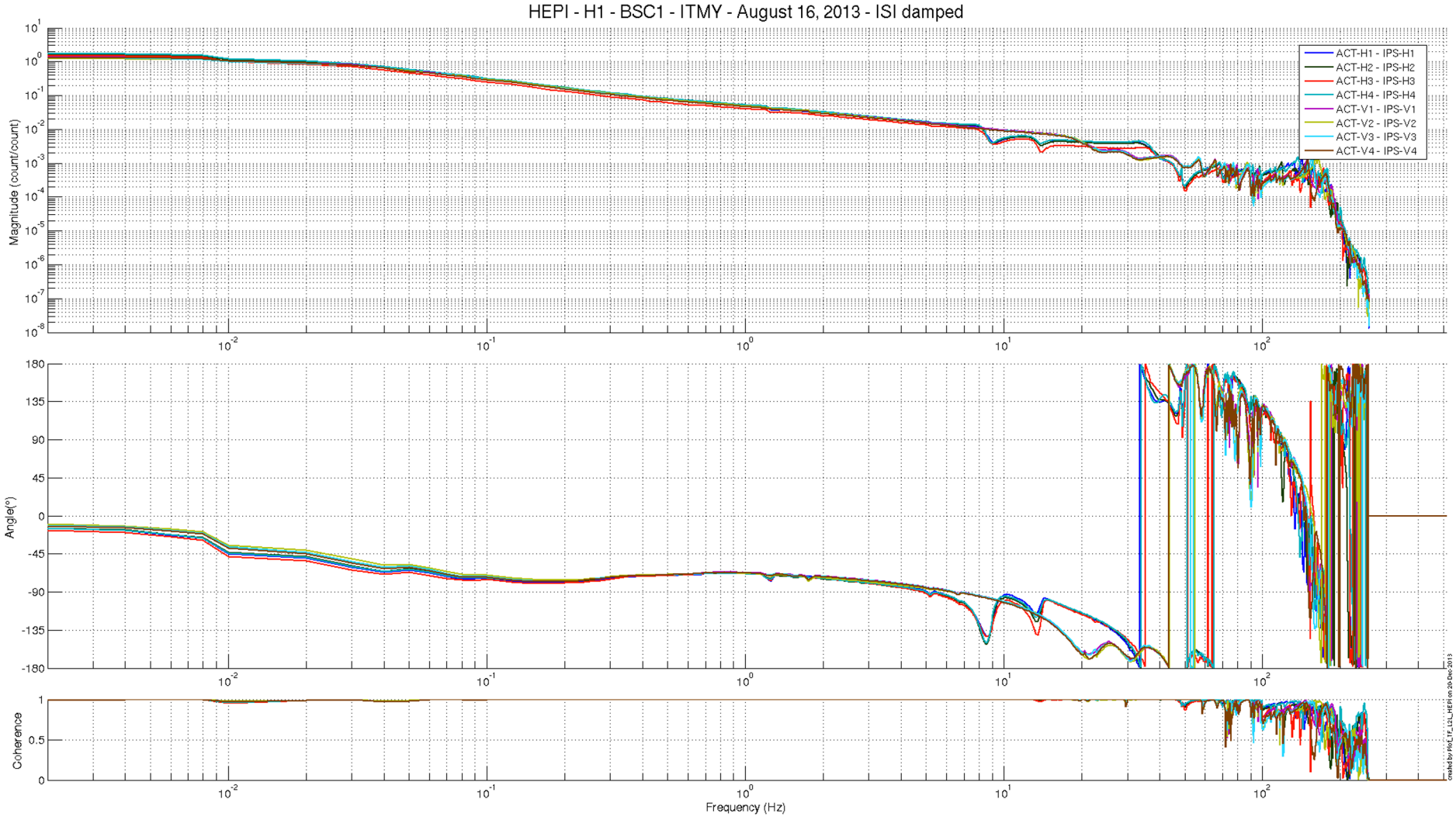
- Actuators and horizontal L4Cs are in phase in this example. No sign correction needed in the input symmetrization filters of the Horizontal L4Cs

- Actuators and vertical L4Cs are out of phase in this example. A sign correction is necessary in the input symmetrization filters of the vertical L4Cs



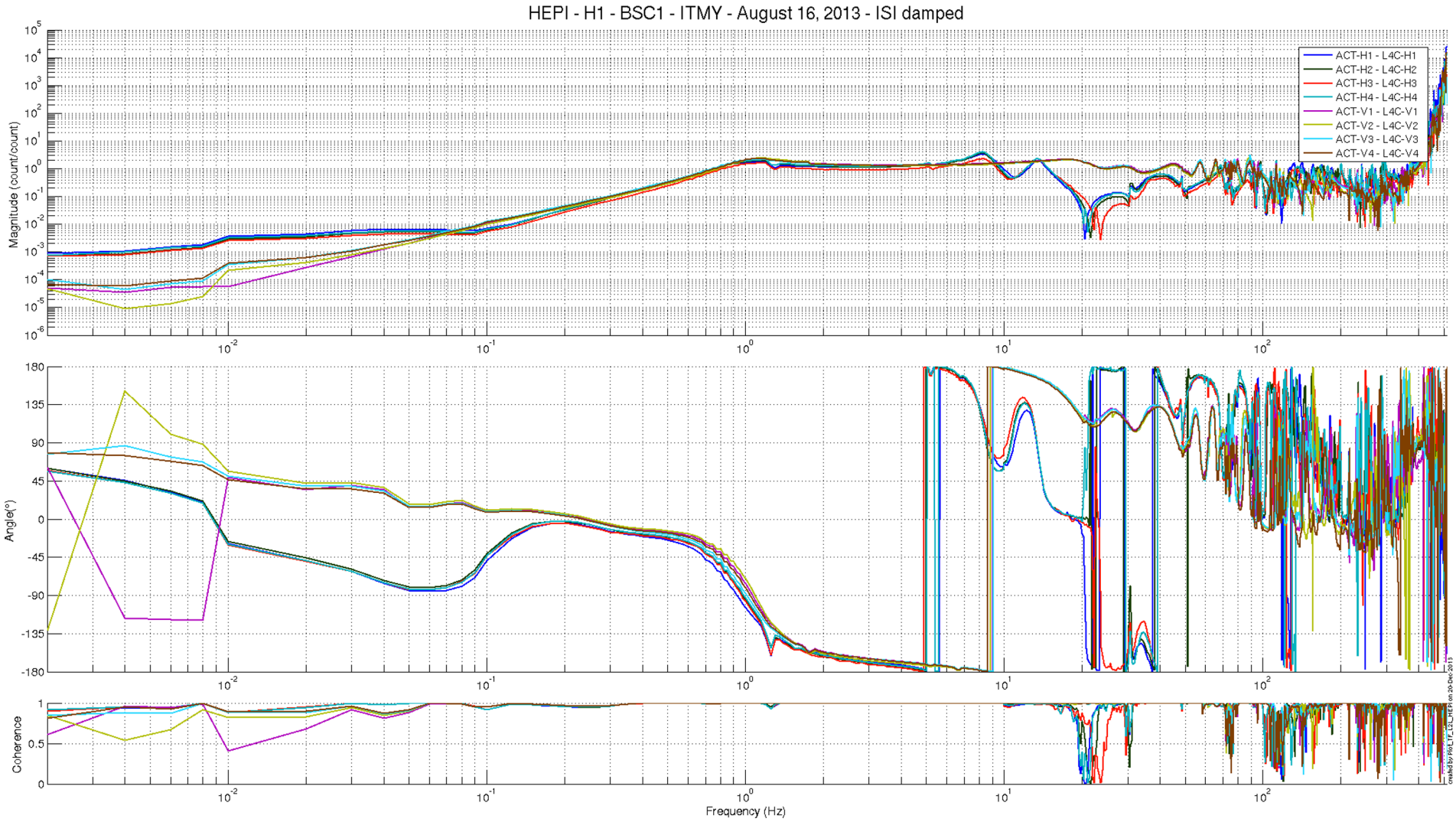
*** Local to local transfer function: from local actuator "Exc channel" to "IN1 channel" in the local sensor input filter's. Only the "Comp filter" must be engaged in the actuator bank (to partially revert the coil driver and actuator frequency response).**

BSC HEPI: Actuators and IPS are in phase.



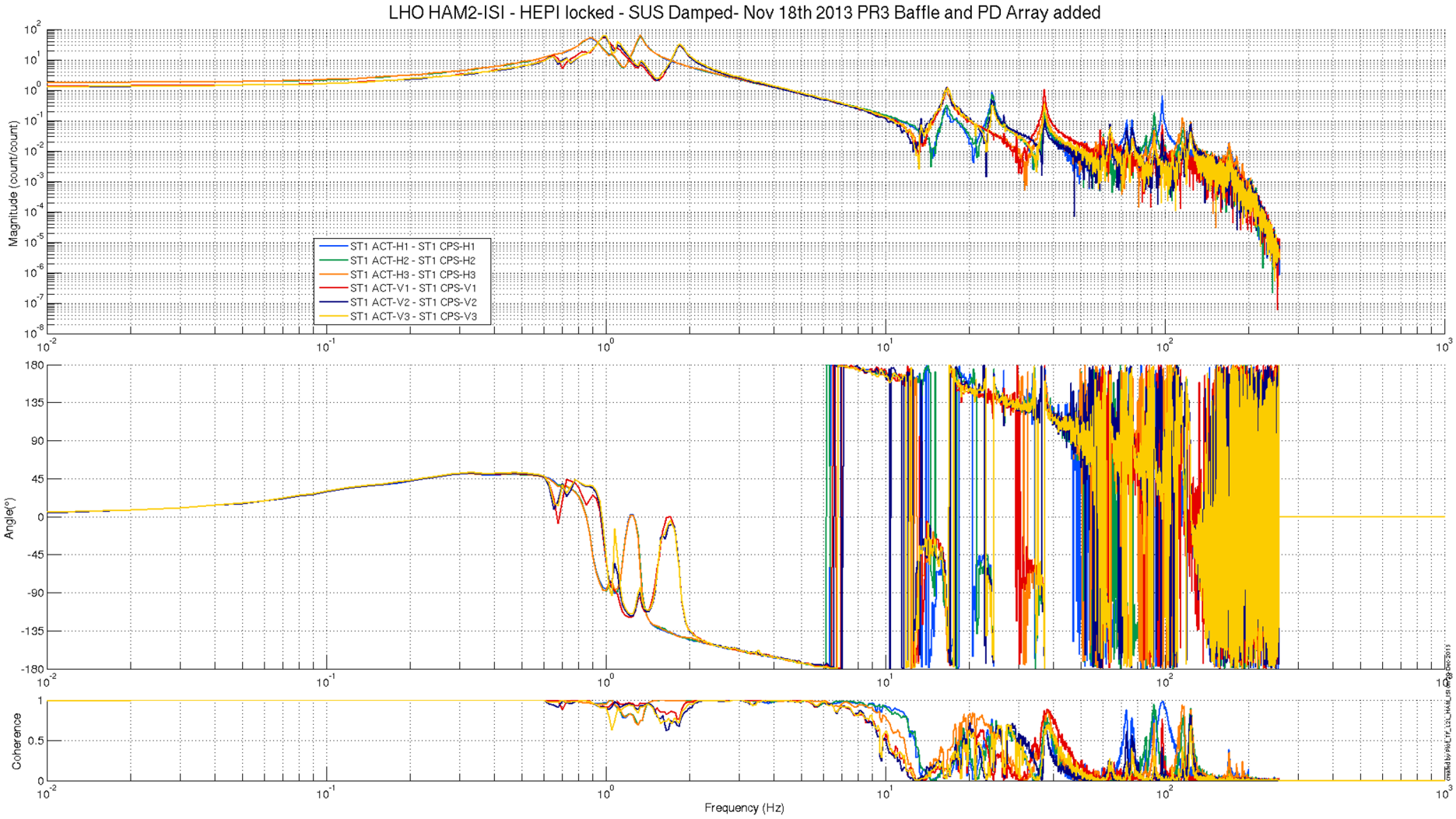
BSC-HEPI:

Actuators and L4Cs are out of phase. This is corrected in the symetrization filters.

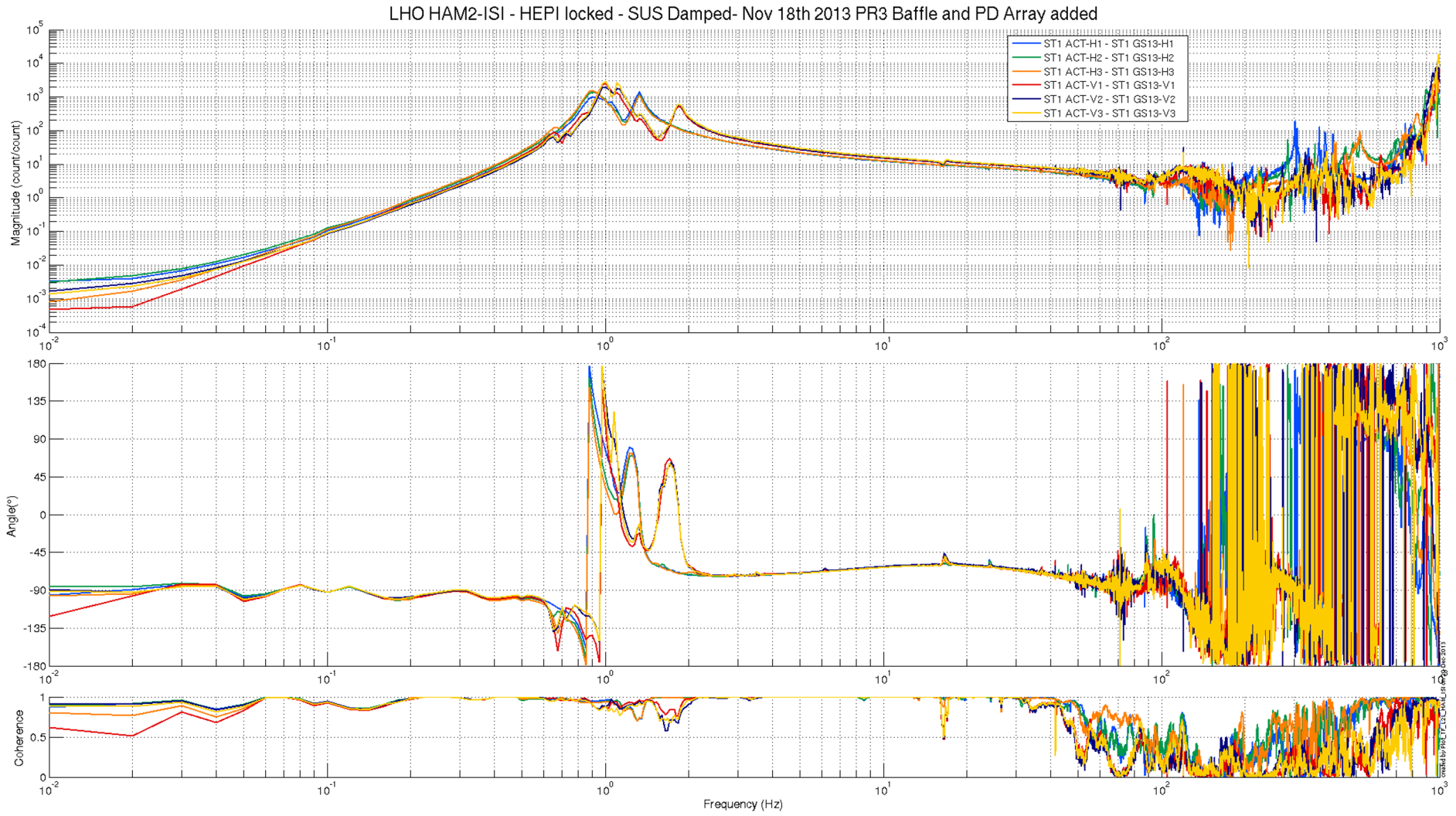


Measured with te ISI damped

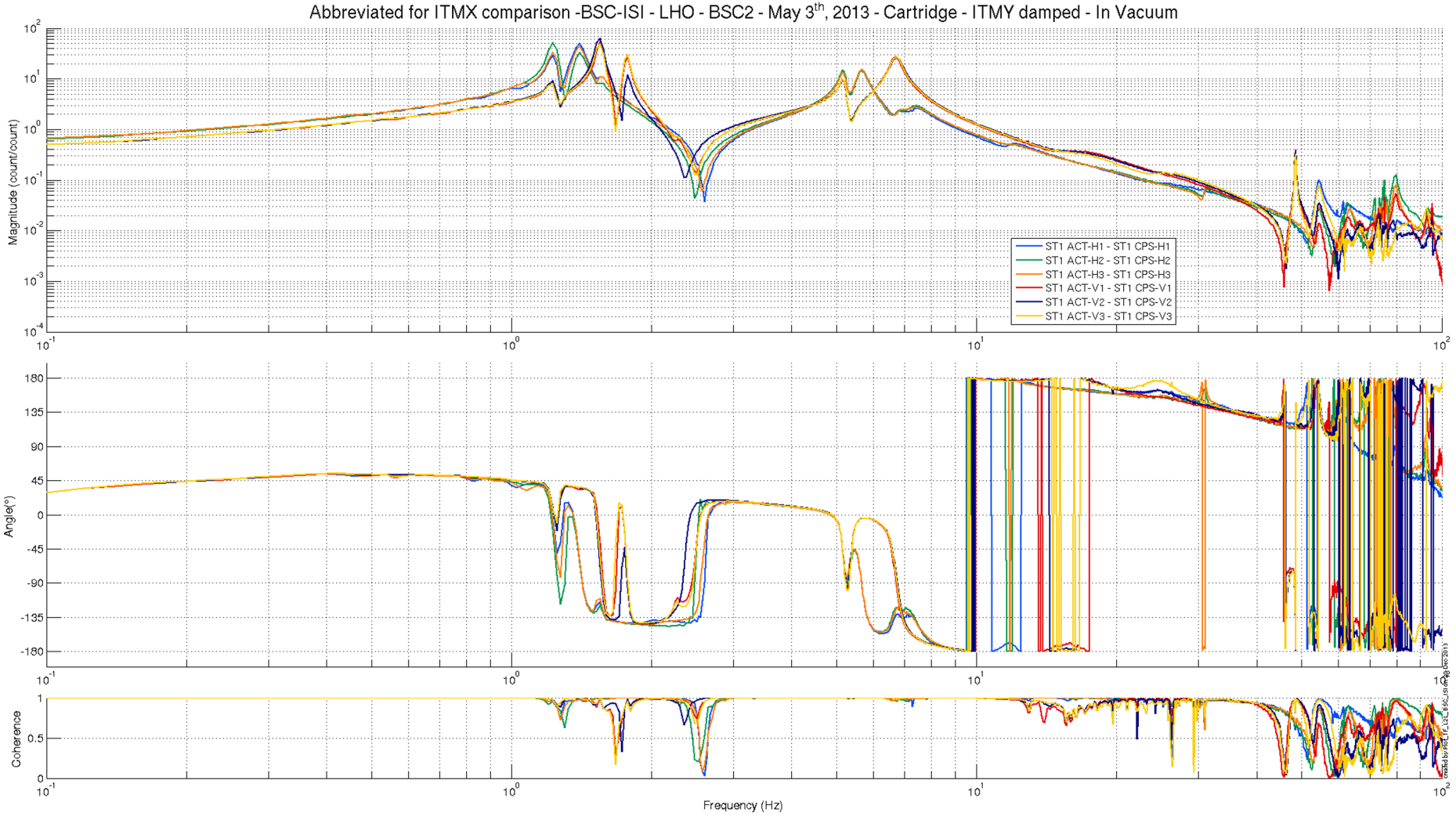
HAM-ISI: Actuators and CPS are in phase.



HAM-ISI: Actuators and GS13 are in phase.



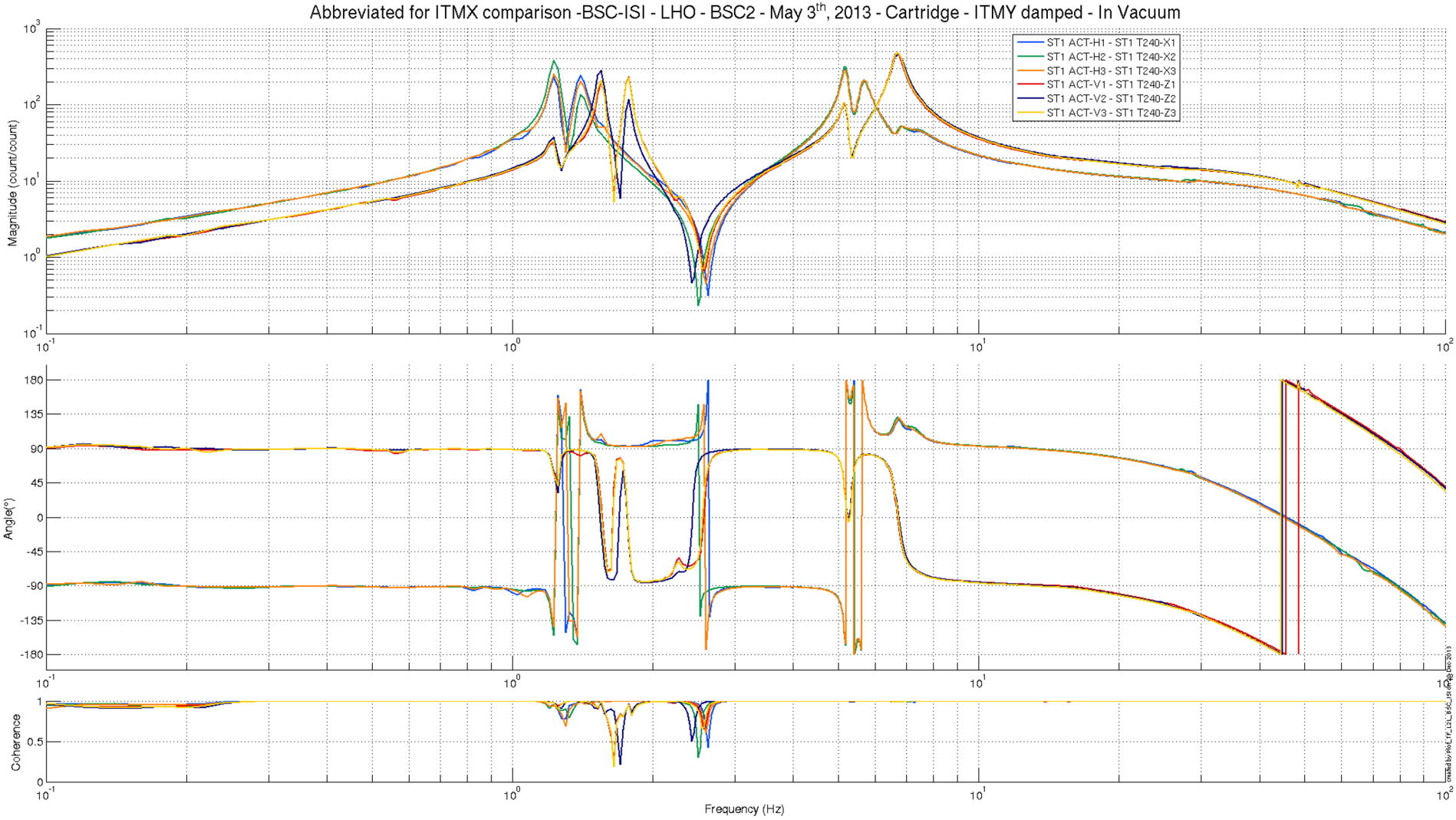
BSC-ISI: Stage1 Actuators and CPS are in phase.



BSC-ISI: Stage 1 T240

- Actuators and Horizontal T240s are out of phase.
- Actuators and Vertical T240s are in phase.

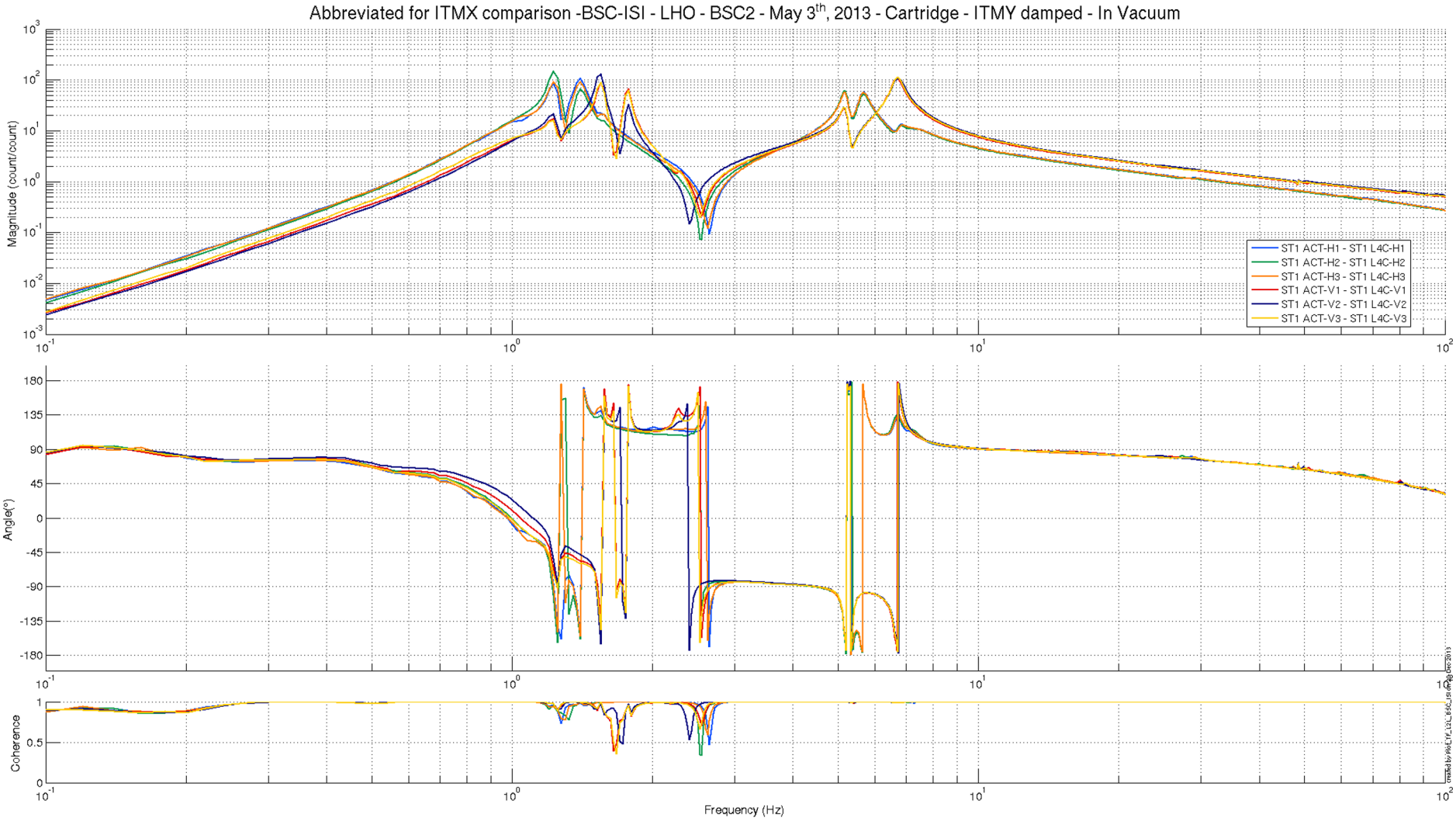
No symmetrization Filters
Sign in the blend?
Cross couplings in matrices ok?



Analog gain mode?

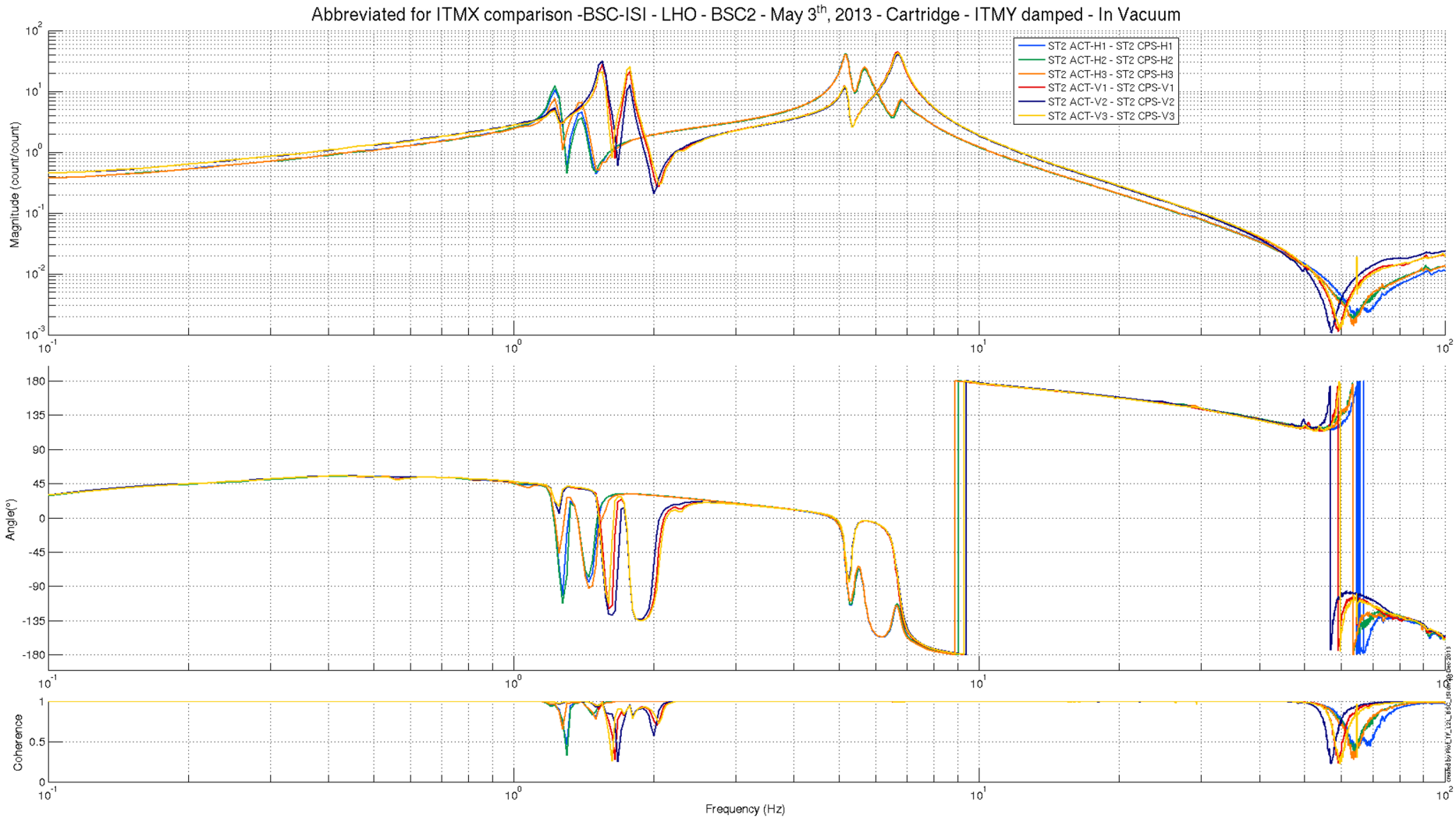
BSC-ISI:

Stage 1 Actuators and L4Cs are out of phase. This is corrected in the symetrization filters.



Analog gain mode?

BSC-ISI: Stage 2 Actuators and CPS are in phase.



BSC-ISI: Stage 2 Actuators and GS13s are in phase.