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MEMORANDUM

DATE: October 26, 2012

TO: Peter Fritschel
FROM: Mike Smith
SUBJECT: ALS Beams @ HAM1
Refer to: LIGO-L1200282-v5

This technical note describes the locations of the ALS and POB beams on HAM1, for the L1 and H1 interferometers.

The analysis was revised to include the effect of switching the orientation of the CPy wedge to the same side as the CPx; this causes the ALS X and ALS Y beams to be much closer together.

The X and Y arm ALS 532 nm beams were launched inside the arm cavity before the ITMHR surface, collinear with the arm cavity beam.

The POB beam and the ALS beams transmit through the HR and AR surfaces of PR2 and are focused by a 1.5 M radius of curvature mirror, then directed by steering mirrors through the center of the input Septum window VP1 between HAM 1 and HAM2 onto an ISC steering mirror on HAM 1, approximately at the center of HAM1.

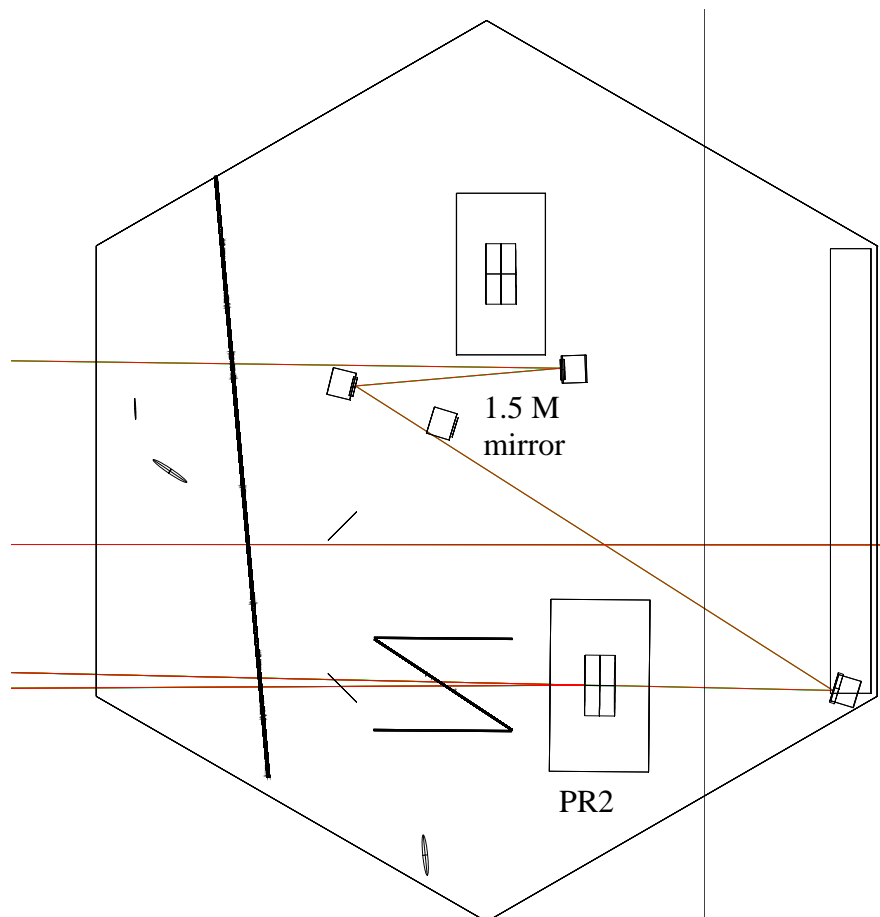


Figure 1: ALS Beams Steering on HAM3

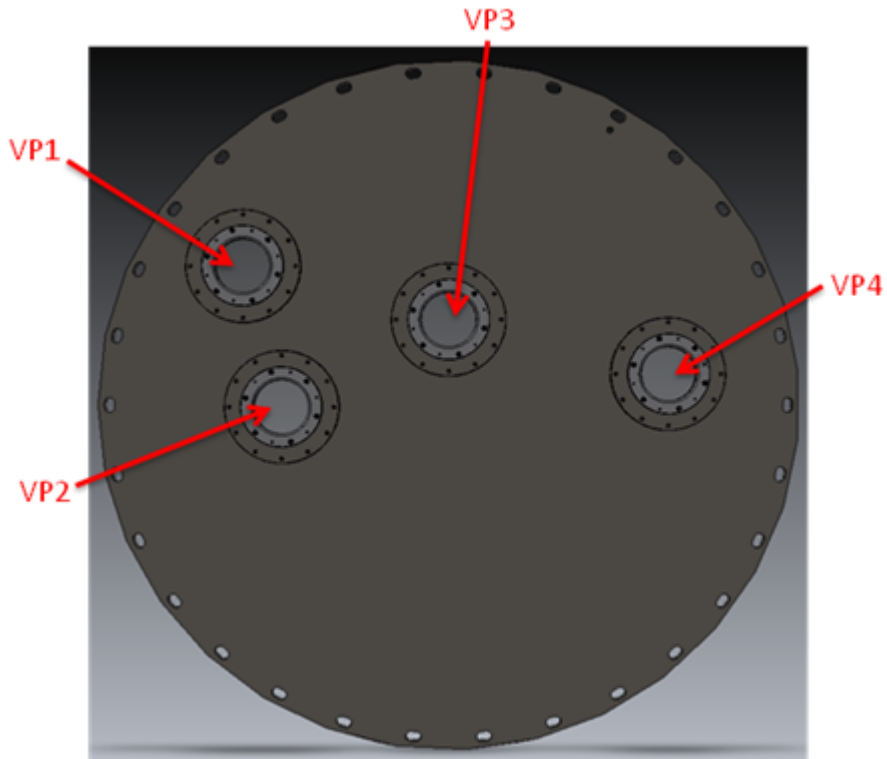


Figure 2: Input Septum Plate Viewport Naming Convention, as Viewed from HAM1 (VP1 is used for the ALS beams)

The 1064nm POB beam and the 532 nm ALS beams principal rays were modeled using ZEMAX under two conditions: 1) the CPx and CPy wedge in opposite orientations, and 2) in the same orientation.

A target representing the steering mirror on HAM 1 was placed near the center of HAM1—the actual location of the steering mirror will be determined by ISC Group.

The ZEMAX layout of the ALS steering mirror and the ALS and POB beams at HAM1 are shown in the following figures.

1. CP WEDGES IN OPPOSITE ORIENTATION: CPy -X, CPx -Y

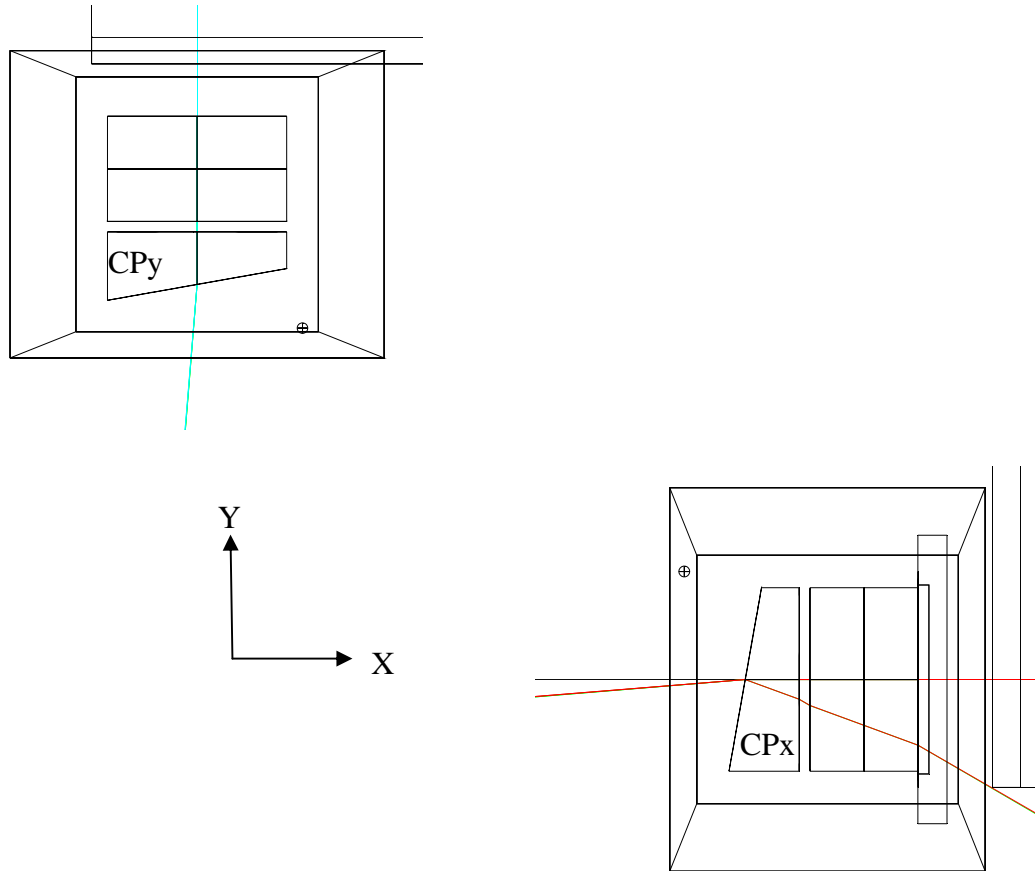


Figure 3: CPx and CPy with Opposite Orientation (note: the wedge angles are exaggerated for emphasis); CPx Thick Side in -Y Direction, CPy Thick Side in -X Direction

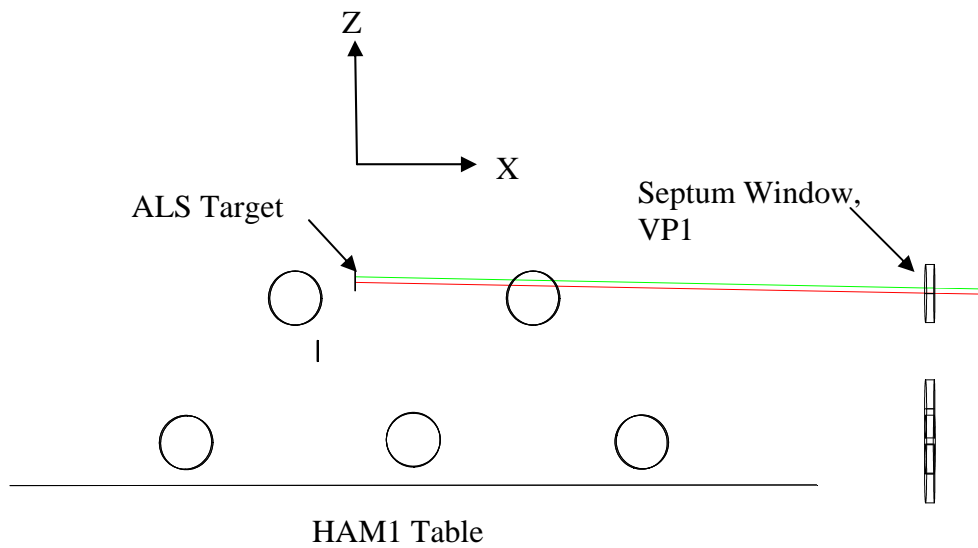


Figure 4: H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam)

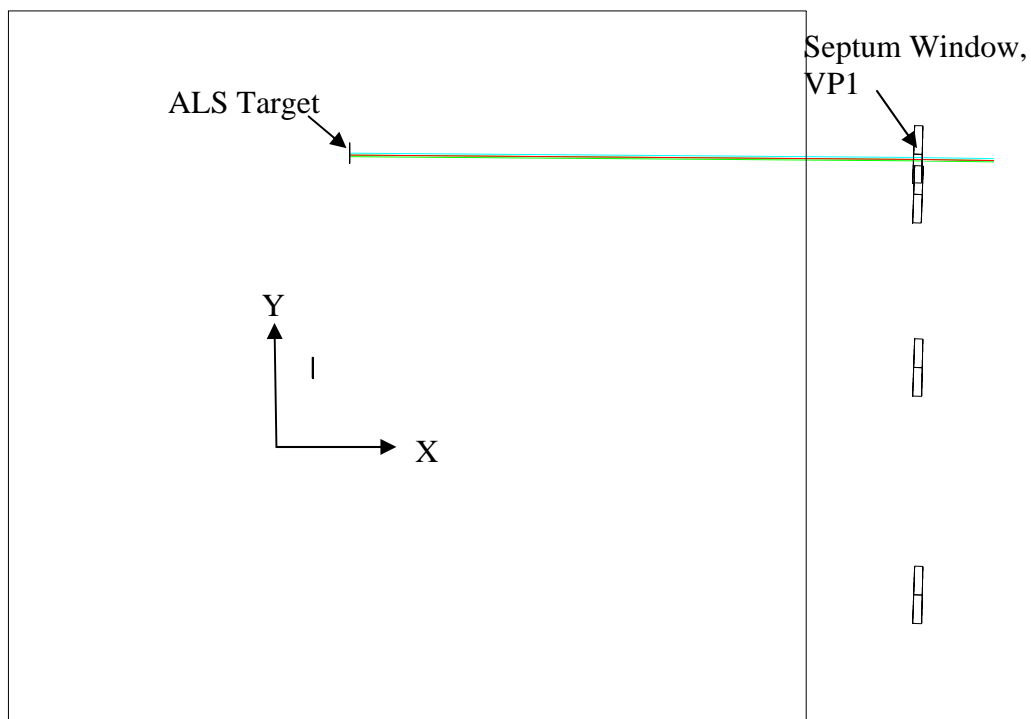


Figure 5: H1 HAM1 Plan View (note: the blue ALS Y beam is in +Y direction, and the green ALS X beam is in -Y direction with respect to the red POB beam)

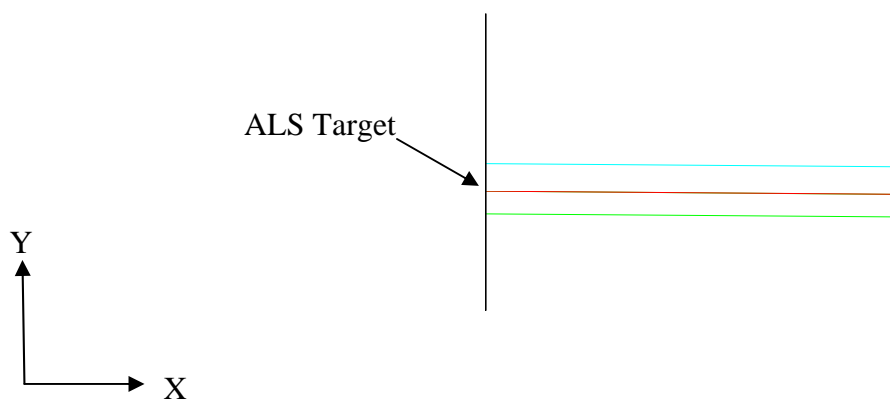


Figure 6: H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y is in the +Y direction, and the green ALS X beam is in the -Y direction with respect to the red POB beam)

2. CP WEDGES IN SAME ORIENTATION: CP_y +X, CP_x -Y

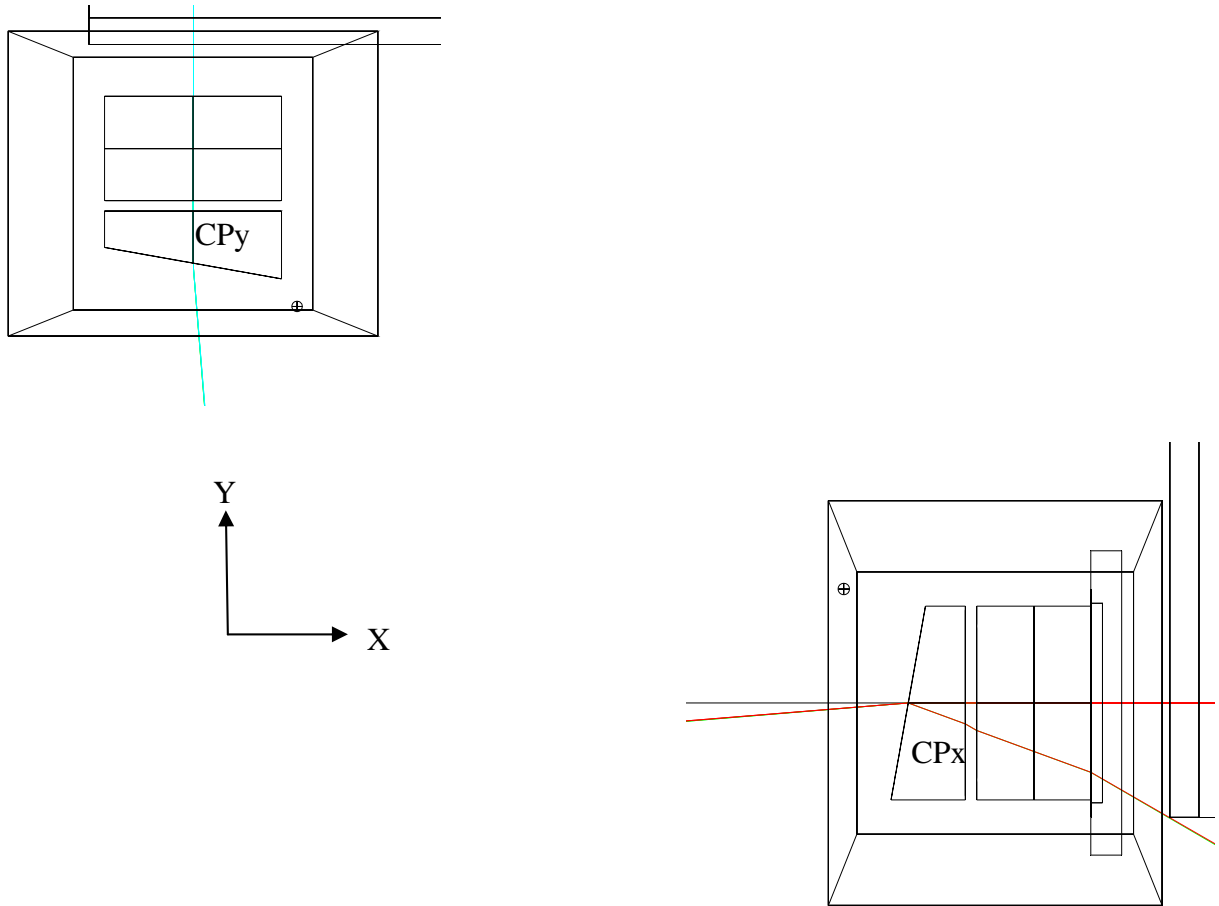


Figure 7: CP_x and CP_y with Same Orientation (note: the wedge angles are exaggerated for emphasis); CP_x Thick Side in -Y Direction, CP_y Thick Side in +X Direction

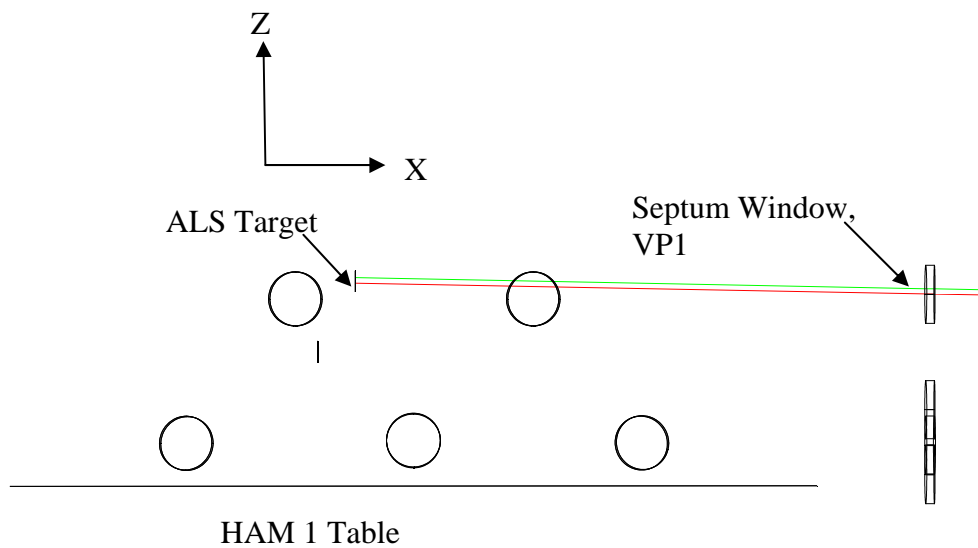


Figure 8: H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam)

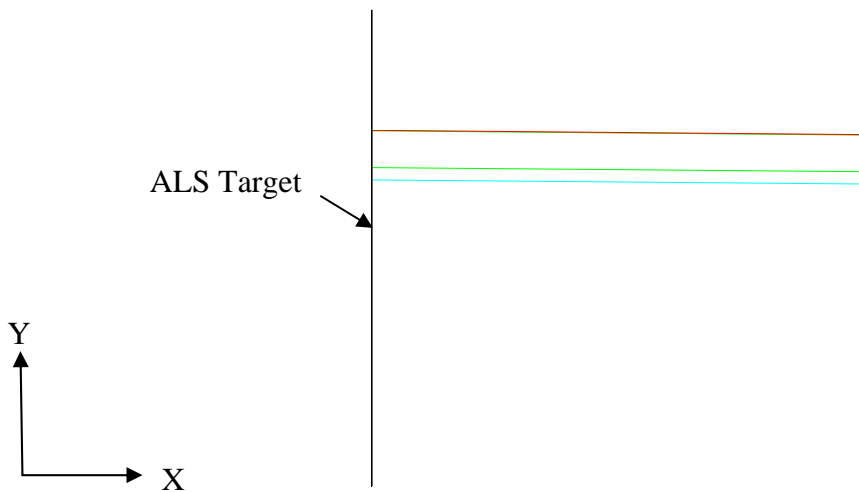


Figure 9: H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y beam has Flipped over to the --Y direction, and the green ALS X beam is still in the -Y direction with respect to the red POB beam)

3. CP WEDGES IN SAME ORIENTATION: CPy -X, CPx +Y

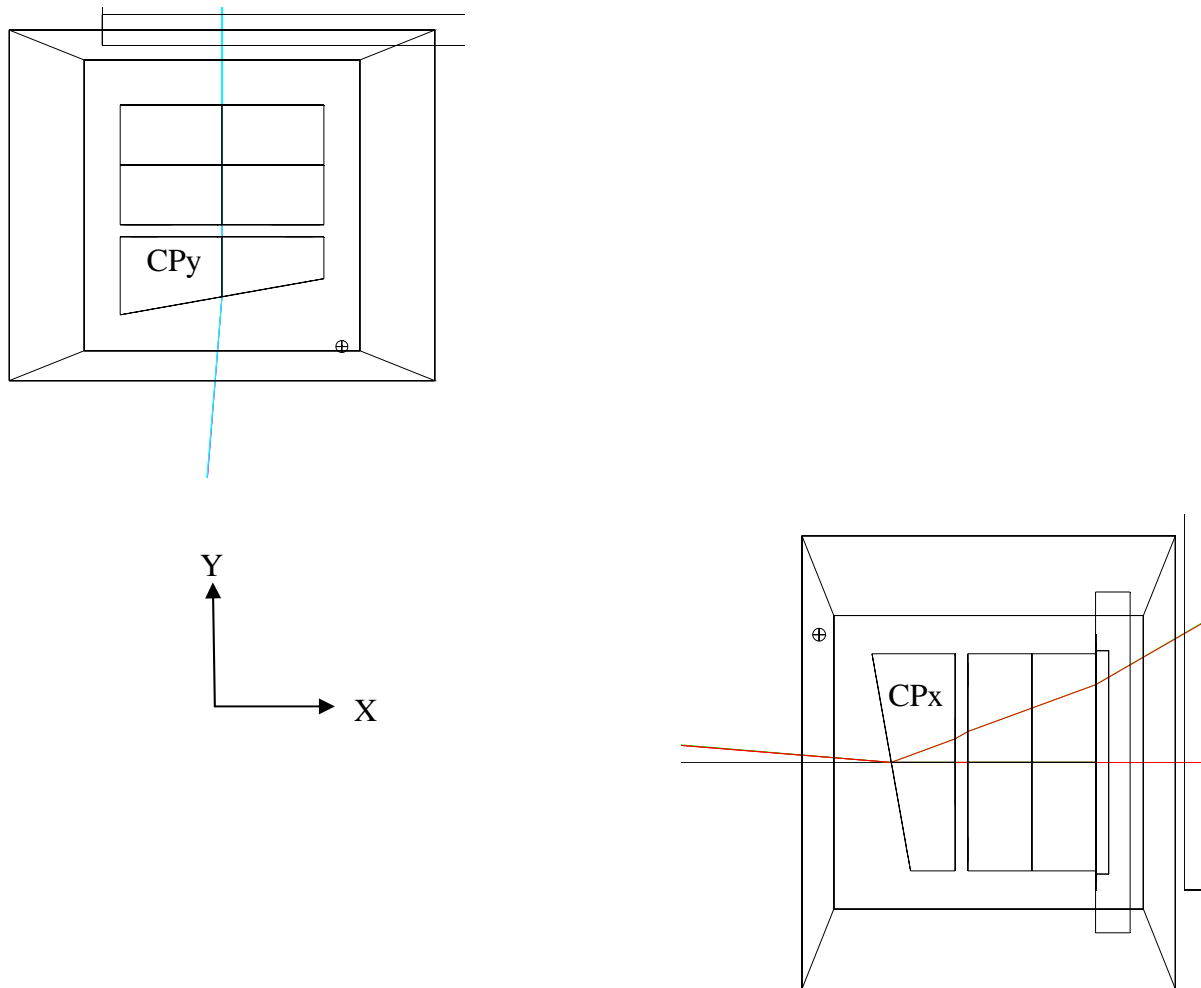


Figure 10: CPx and CPy with Same Orientation (note: the wedge angles are exaggerated for emphasis); CPx Thick Side in -Y Direction, CPy Thick Side in +X Direction

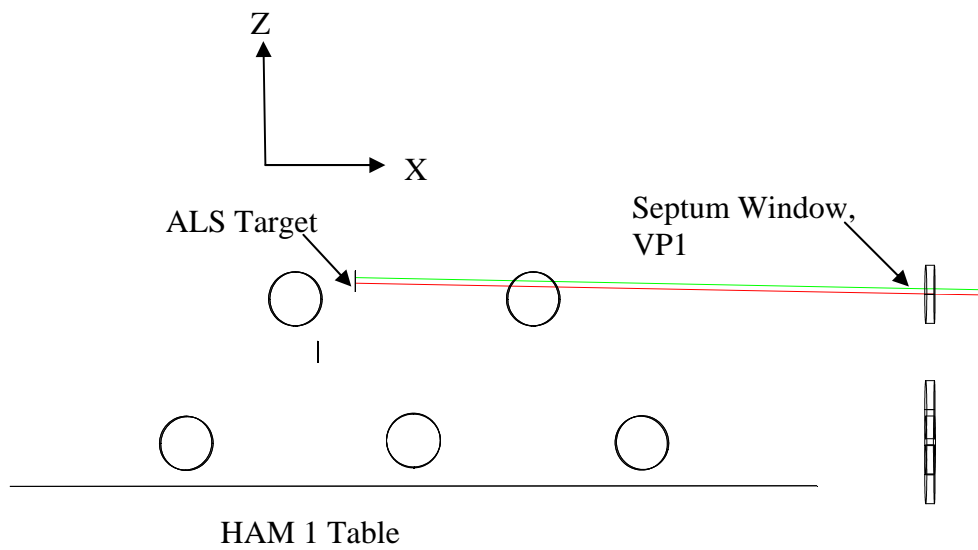


Figure 11: H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam)

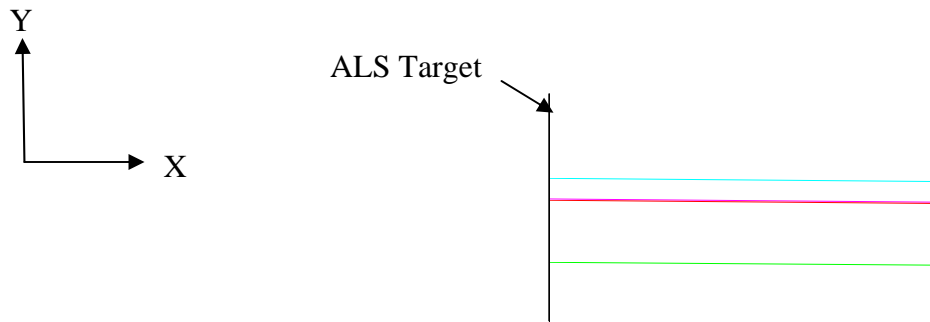


Figure 12: H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y beam has Flipped over to the --Y direction, and the green ALS X beam is still in the -Y direction with respect to the red POB beam)

4. NO CP WEDGES

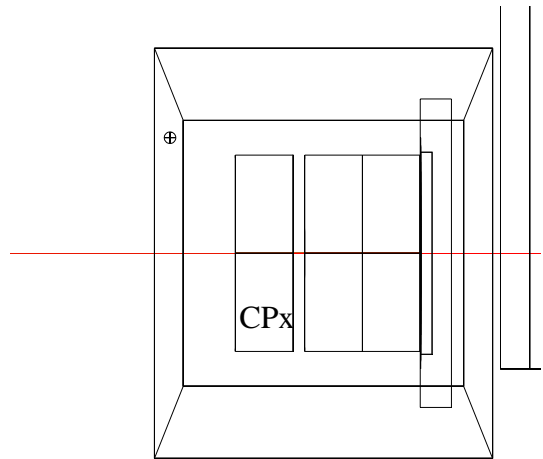
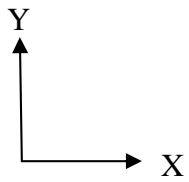
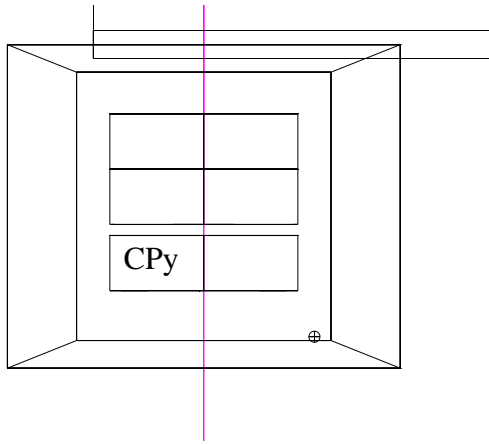


Figure 13: CPx and CPy with No Wedge

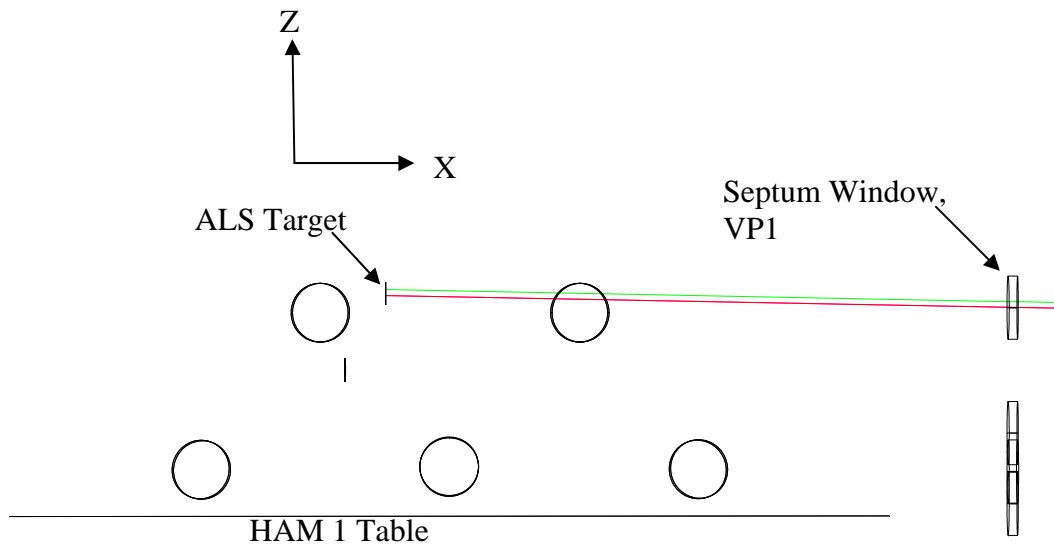


Figure 14: H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam). The vertical separation is caused primarily by the PR2 wedge, and partly by the ITM wedge.

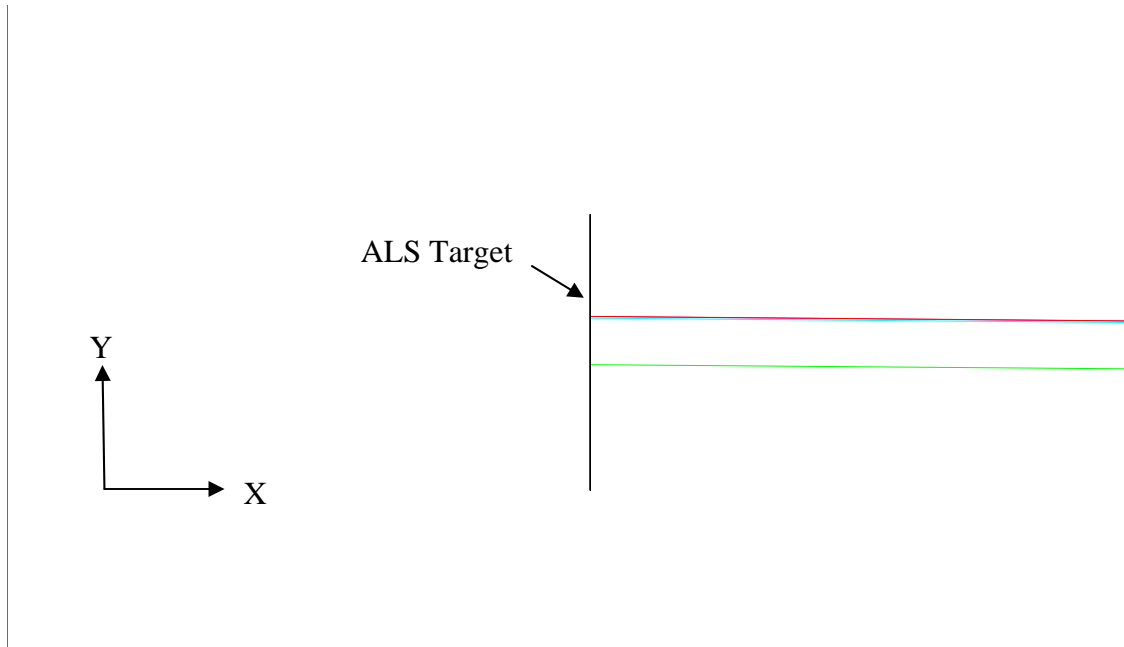


Figure 15: H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y beam is collinear with the red POB beam; and the green ALS X is deviated in the $-Y$ direction with respect to the red POB beam due to the BS wedge.)

5. ALS Beam Coordinates

The global coordinates of the ALS and POB beams, and the beam separations in the Y and Z coordinate directions are given in the following table. Note that the positions of the ALS beams on HAM1 are critically dependent upon the alignment of the main IFO X and Y arm beams at the BS and PR3 mirrors. The main beams were accurately aligned for the updated results in LIGO-L1200282-v3.

- **Opposite CP Wedge Angle Orientation: CPy -X, CPx -Y**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of each ALS beam from the POB beam is > 3.8 mm. The separation between ALS X and ALS Y is 8.5 mm.

Table 1: Beam Global Coordinates at HAM1, Opposite CP Wedge Orientation: CPy -X, CPx -Y

Beam	Global Coordinates at HAM1			Separation from POB			Separation between ALS		
	X, mm	Y, mm	Z, mm	ΔX , mm	ΔY , mm	ΔZ , mm	ΔX , mm	ΔY , mm	ΔZ , mm
ALS X	-22864.0	503.3	288.7	0.0	-3.8	13.3	0.0	-8.5	0.0
ALS Y	-22864.0	511.8	288.7	0.0	4.6	13.3			
POB	-22864.0	507.1	275.5						

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table 2: Ray Vector Angles at HAM1, Opposite CP Wedge Orientation: CPy -X, CPx -Y

BEAM	GLOBAL INCIDENT RAY VECTOR COSINES			GLOBAL INCIDENT RAY VECTOR ANGLES, deg		
	X	Y	Z	X	Y	Z
ALS X	-0.999784	0.007329	0.019463	179.580	NA	1.115
ALS Y	-0.999780	0.007785	0.019462	179.554	NA	1.115
POB	-0.999795	0.007670	0.018736	179.560	NA	1.074

- **Same CP Wedge Angle Orientation: CPy +X, CPx -Y**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of each ALS beam from the POB beam is > 3.9 mm. **The separation between ALS X and ALS Y is 1.3 mm.**

Table 3: Beam Global Coordinates at HAM1, Same CP Wedge Orientation: CPy +X, CPx -Y

Beam	Global Coordinates at HAM1			Separation from POB			Separation between ALS		
	X, mm	Y, mm	Z, mm	ΔX , mm	ΔY , mm	ΔZ , mm	ΔX , mm	ΔY , mm	ΔZ , mm
ALS X	-22864.0	520.4	288.7	0.0	-3.9	13.3	0.0	1.3	0.0
ALS Y	-22864.0	519.1	288.7	0.0	-5.2	13.3			
POB	-22864.0	524.3	275.4						

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table 4: Ray Vector Angles at HAM1, Same CP Wedge Orientation

BEAM	GLOBAL INCIDENT RAY VECTOR COSINES			GLOBAL INCIDENT RAY VECTOR ANGLES, deg		
	X	Y	Z	X	Y	Z
ALS X	-0.999777	0.008258	0.019461	179.527	NA	1.115
ALS Y	-0.999777	0.008187	0.019461	179.531	NA	1.115
POB	-0.999788	0.008603	0.018735	179.507	NA	1.073

- **Same CP Wedge Angle Orientation: CPy -X, CPx +Y**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of each ALS beam from the POB beam is > 4.8 mm. The separation between ALS X and ALS Y is 18.5 mm.

Table 5: Beam Global Coordinates at HAM1, Same CP Wedge Orientation: CPy -X, CPx +Y

Beam	Global Coordinates at HAM1			Separation from POB			Separation between ALS		
	X, mm	Y, mm	Z, mm	ΔX , mm	ΔY , mm	ΔZ , mm	ΔX , mm	ΔY , mm	ΔZ , mm
ALS X	-22864.0	499.9	288.7	0.0	-13.6	13.3	0.0	-18.5	0.0
ALS Y	-22864.0	518.4	288.6	0.0	4.8	13.3			
POB	-22864.0	513.6	275.4						

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table 6: Ray Vector Angles at HAM1, Same CP Wedge Orientation: CPy -X, CPx +Y

BEAM	GLOBAL INCIDENT RAY VECTOR COSINES			GLOBAL INCIDENT RAY VECTOR ANGLES, deg		
	X	Y	Z	X	Y	Z
ALS X	-0.999783	0.007385	0.019458	179.577	NA	1.115
ALS Y	-0.999776	0.008380	0.019456	179.520	NA	1.115
POB	-0.999790	0.008254	0.018730	179.527	NA	1.073

- No CP Wedge Angle Orientation**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of ALS X beam from the POB beam is 8.8 mm. The separations of ALS Y beam from the POB beam is 0.3 mm. The separation between ALS and ALS Y is 8.4 mm.

Table 7: Beam Global Coordinates at HAM1, No CP Wedge

Beam	Global Coordinates at HAM1			Separation from POB			Separation between ALS		
	X, mm	Y, mm	Z, mm	ΔX , mm	ΔY , mm	ΔZ , mm	ΔX , mm	ΔY , mm	ΔZ , mm
ALS X	-22864.0	509.8	288.7	0.0	-8.8	13.3	0.0	-8.4	0.0
ALS Y	-22864.0	518.2	288.7	0.0	-0.3	13.3			
POB	-22864.0	518.5	275.4						

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table 8: Ray Vector Angles at HAM1, No CP Wedge

BEAM	GLOBAL INCIDENT RAY VECTOR COSINES			GLOBAL INCIDENT RAY VECTOR ANGLES, deg		
	X	Y	Z	X	Y	Z
ALS X	-0.999780	0.007799	0.019459	179.553	NA	1.115
ALS Y	-0.999777	0.008254	0.019459	179.527	NA	1.115
POB	-0.999789	0.008406	0.018732	179.518	NA	1.073