

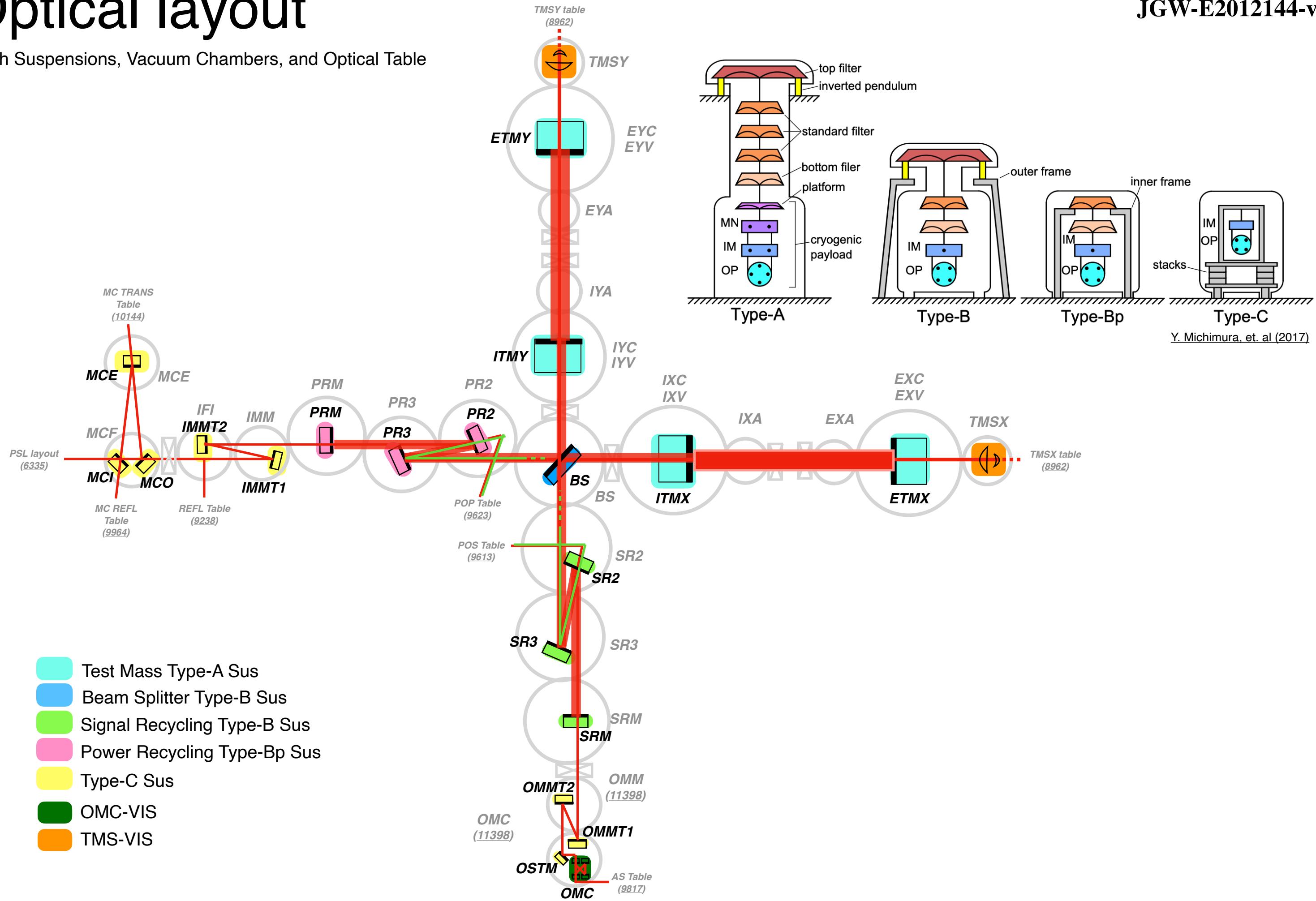
All about  
Vibration Isolation System  
in KAGRA

**JGW-E2012144-v6**

# Optical layout

JGW-E2012144-v6

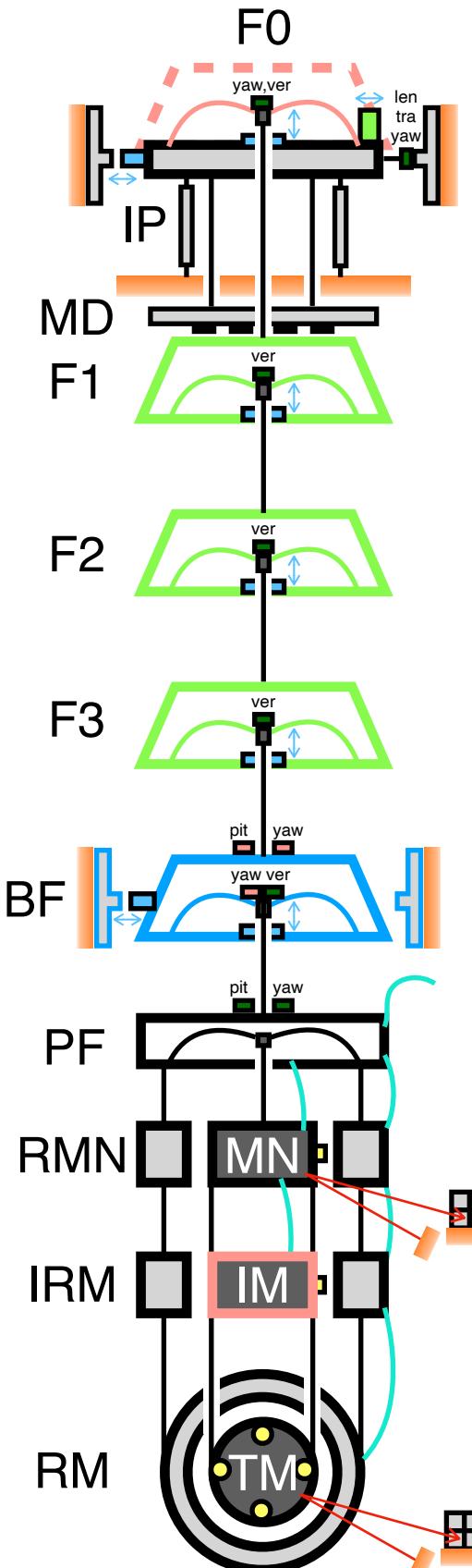
with Suspensions, Vacuum Chambers, and Optical Table



# Suspensions

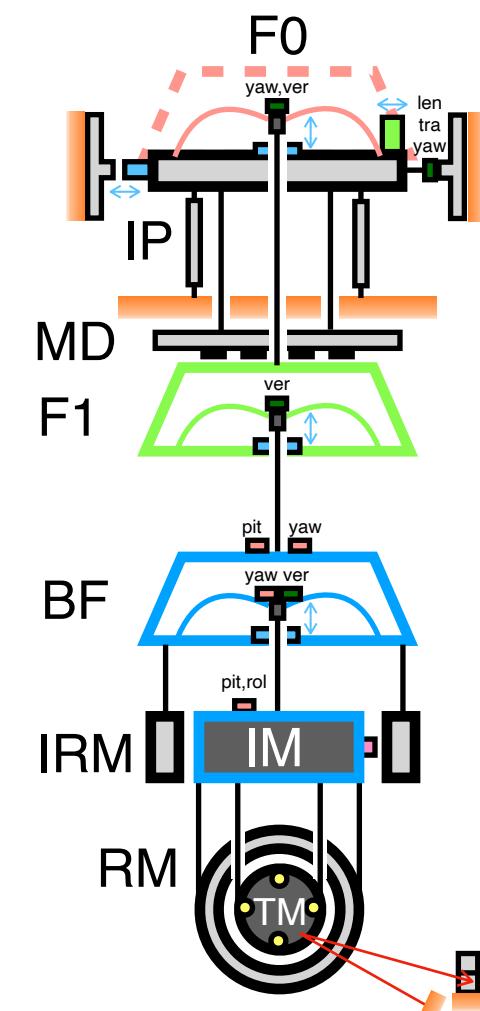
JGW-E2012144-v6

with sensors and actuators



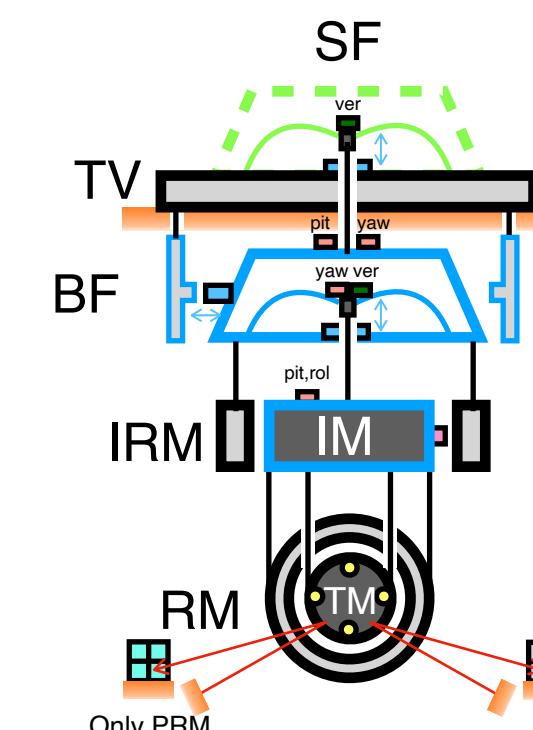
Type-A

- GAS-LVDT/Voice Coil Actuator(VoCo)
- LVDT/VoCo
- Accelerometer
- OSEM
- Optical Lever (OpLev)
- PSD
- CMA
- Photo Sensor (PS)/Coil Magnet Actuator(CMA)
- Stepper motor
- Picomotor
- Magnet



Type-B

- Geometric Anti Spring filter
  - Top Filter (TF)
  - Standard Filter (SF)
  - Bottom Filter (BF)
- IM Intermediate Mass
  - For Type-A
  - For Type-B, Bp (except BS)
  - For Type-C
- LVDT recoil
  - For IP
  - For BF (only Type-A, Bp)



Type-Bp

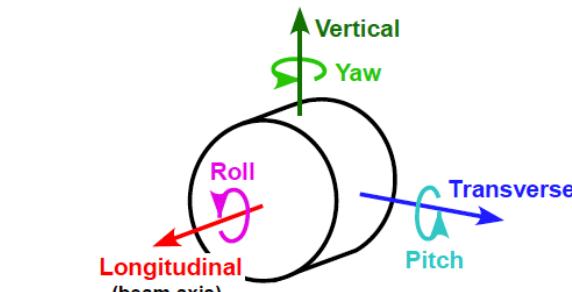
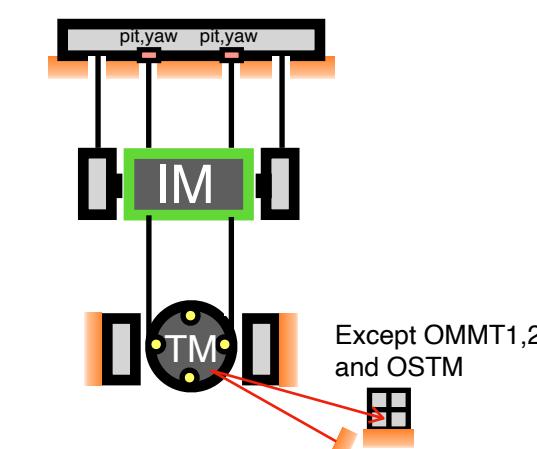


Figure 2.7: Definition of the coordinate system.

from T. Sekiguchi PhD thesis



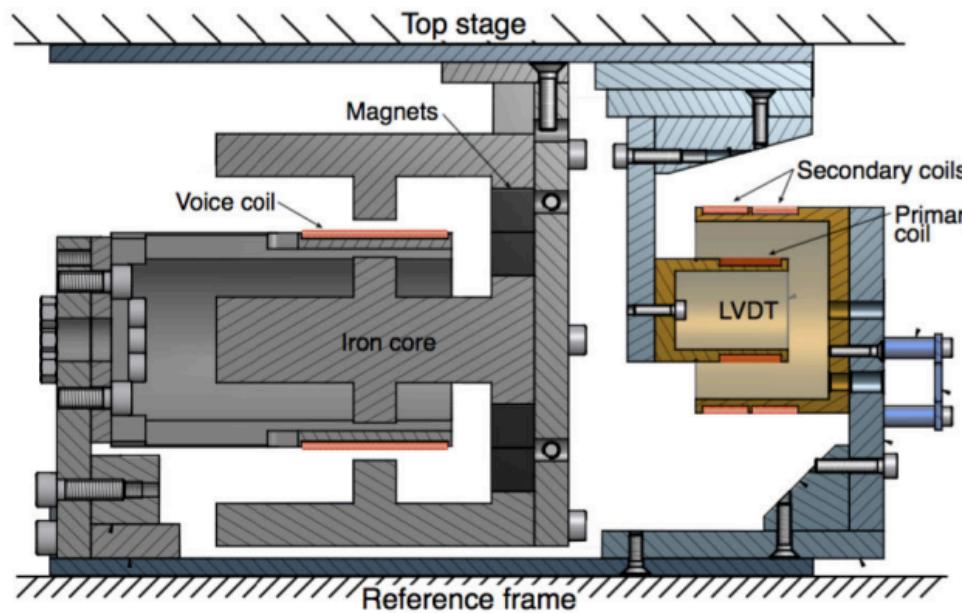
Type-C

# Calibration

JGW-E2012144-v6



## IP-LVDT



CAD view of the LVDT and VoCo

Fig. 1.22 from Joris's PhD thesis

## GAS-LVDT

No picture?

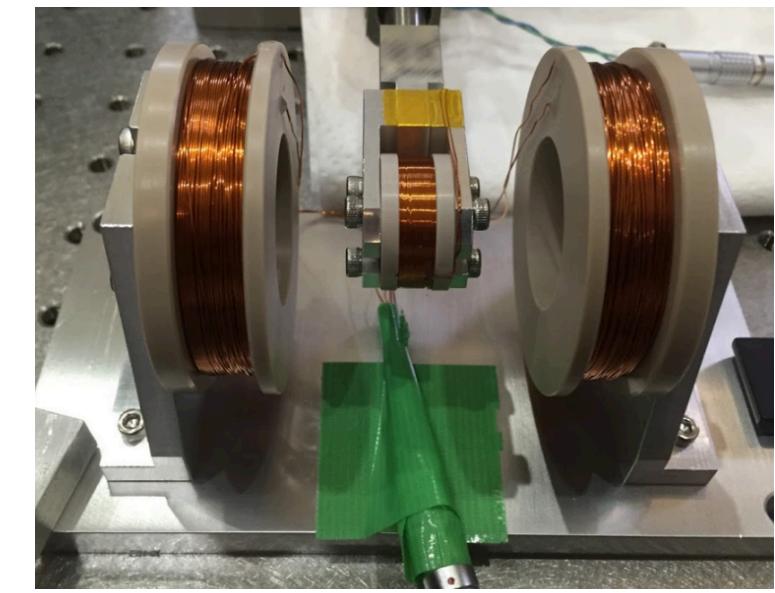
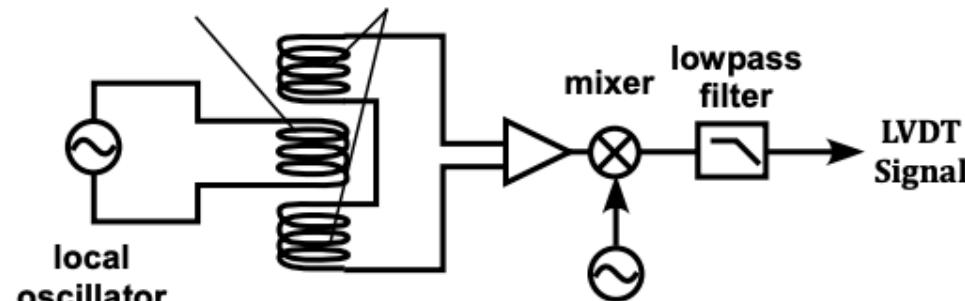


Fig. 6.4 from Yoshinori's PhD thesis

(Primary Coil) (Secondary Coil)  
emitter coil receiver coils

Schematic view of LVDT

Fig. 6.5 from Takanori's PhD thesis

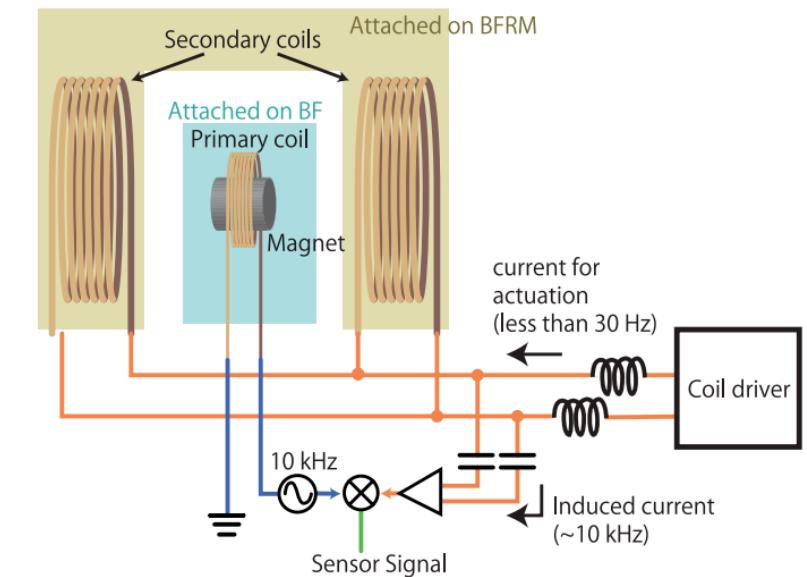
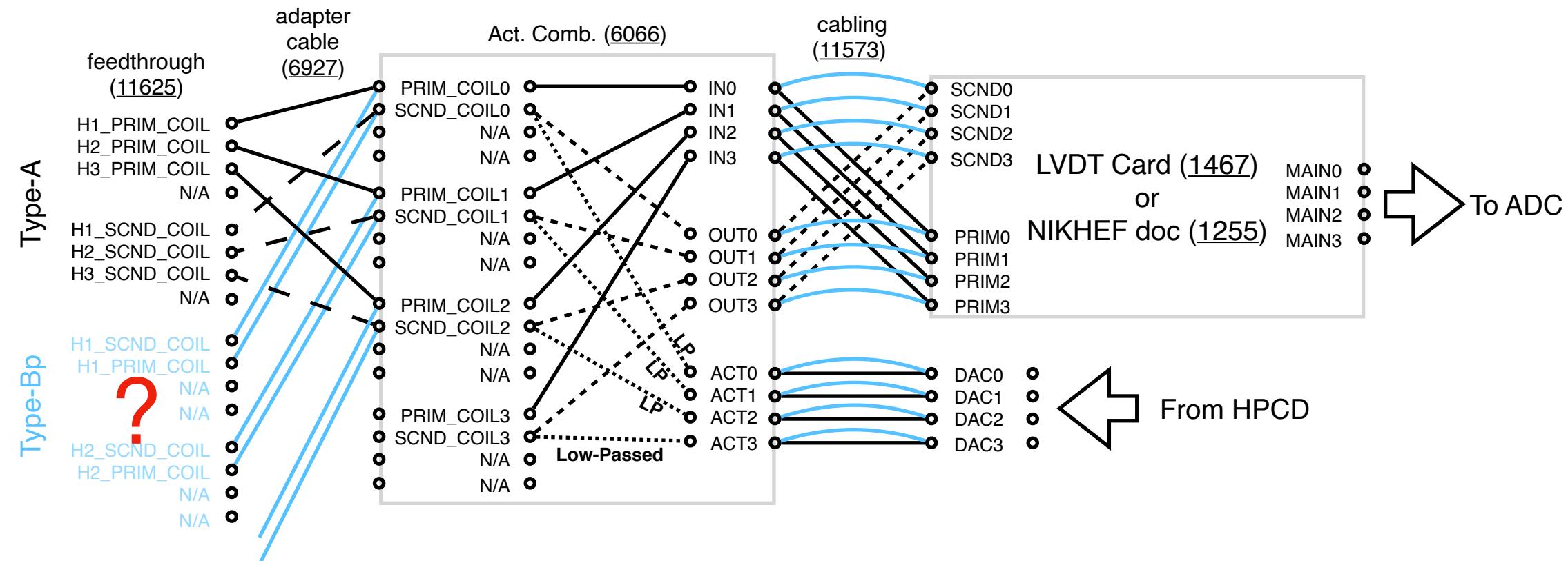
Same as the  
IP-LVDT?

Fig. 5 Y Akiyama et.al (2019)

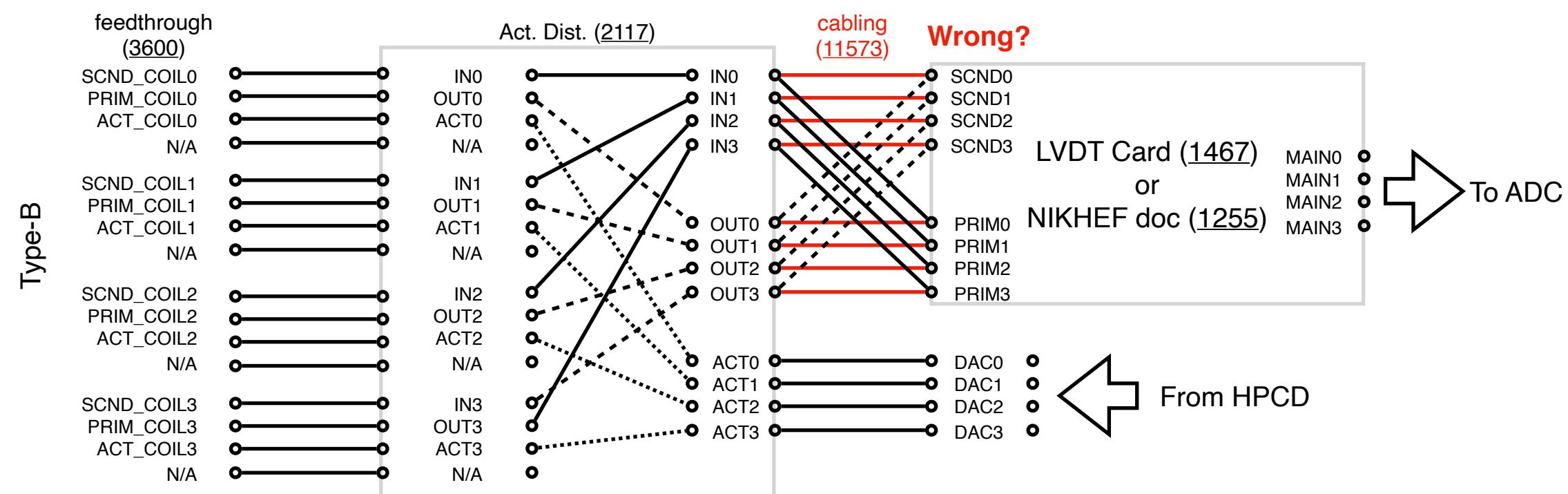
# LVDT connections in O3 (in the H case)

JGW-E2012144-v6

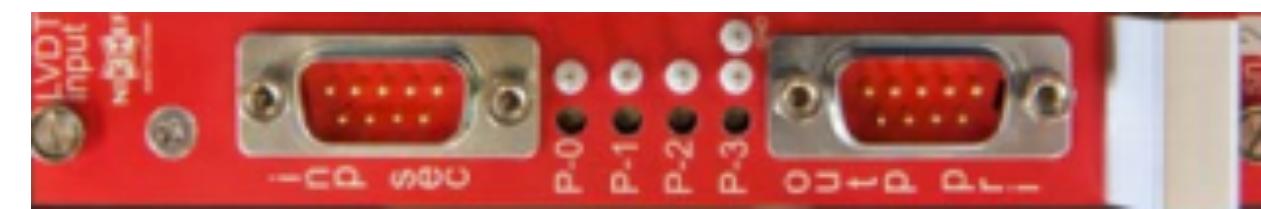
**BF-LVDT**

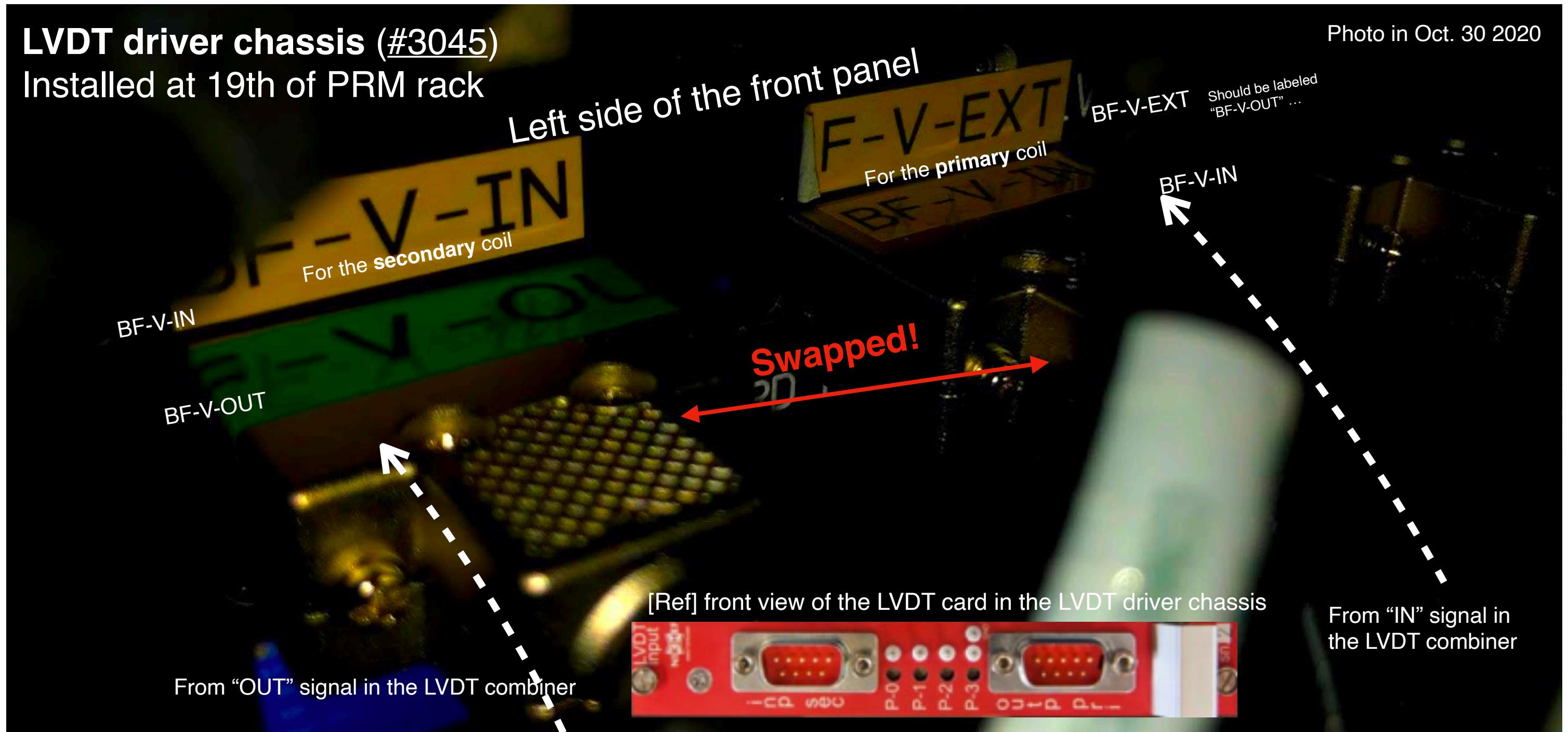


**GAS/IP-LVDT**



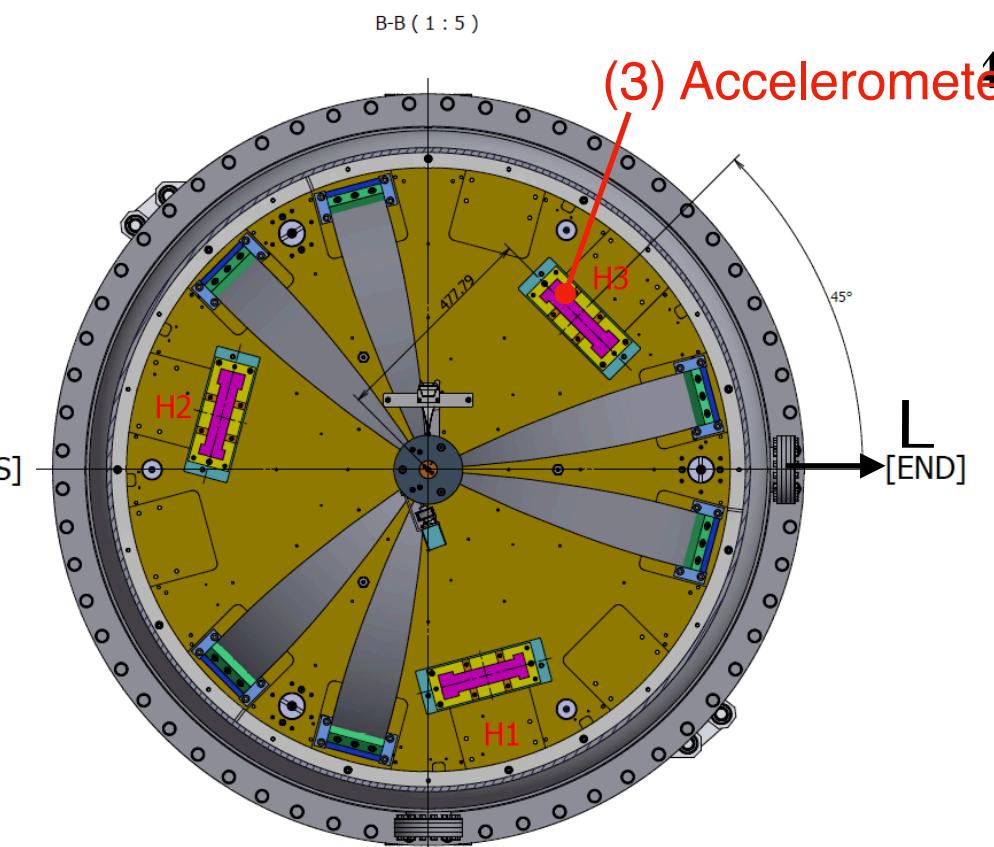
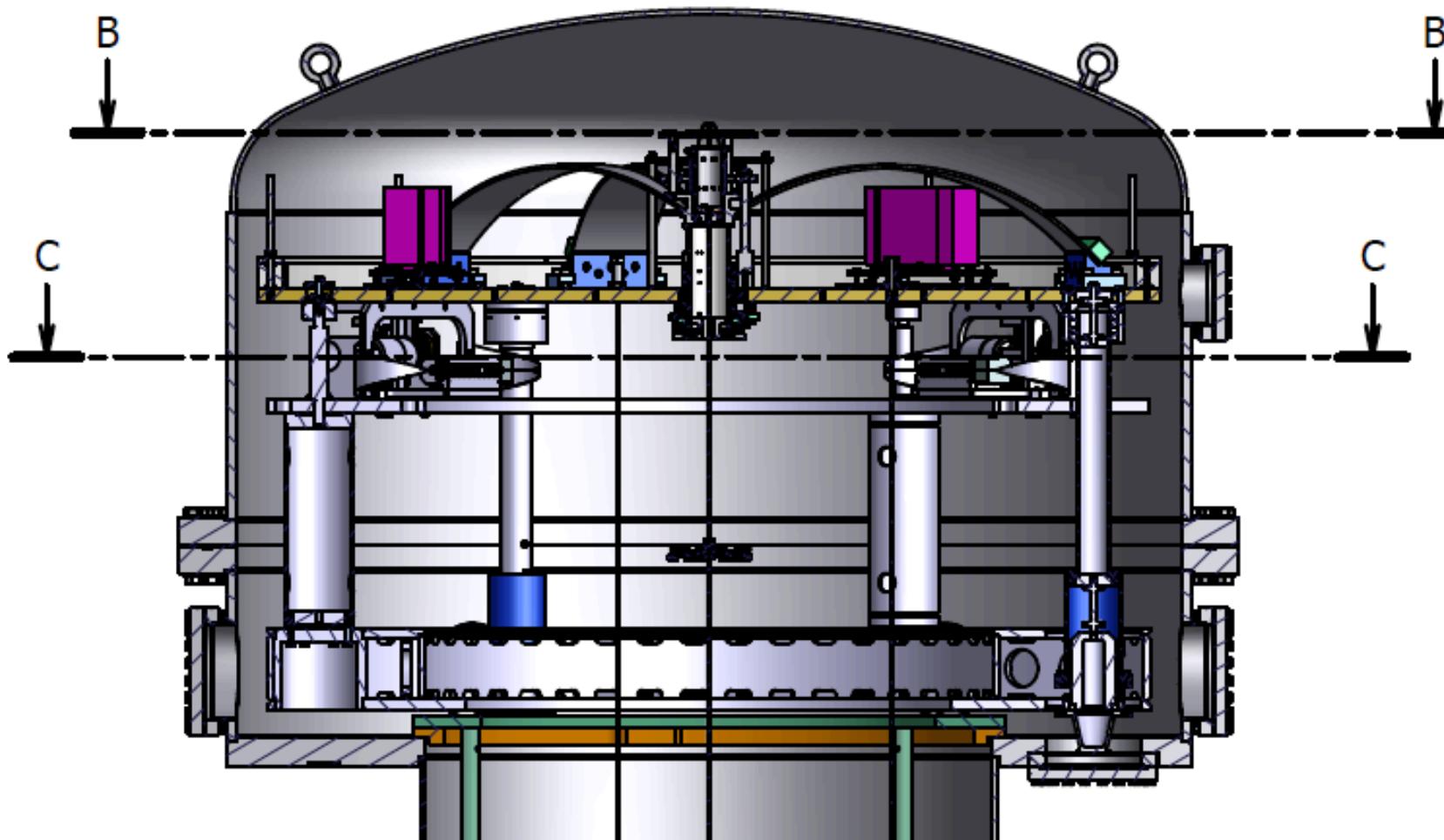
**[Note]** In the TypeB case, at the pin assignment at the feedthrough, the secondary and the primary signal have been swapped out. This means that cabling style like Type-A would be correct. In other word, "IN" signal labeled in both Combiner and Distributor should be connected to the "right" side connector on the front panel of the LVDT driver chassis, which is the connector for the "Primary coil".



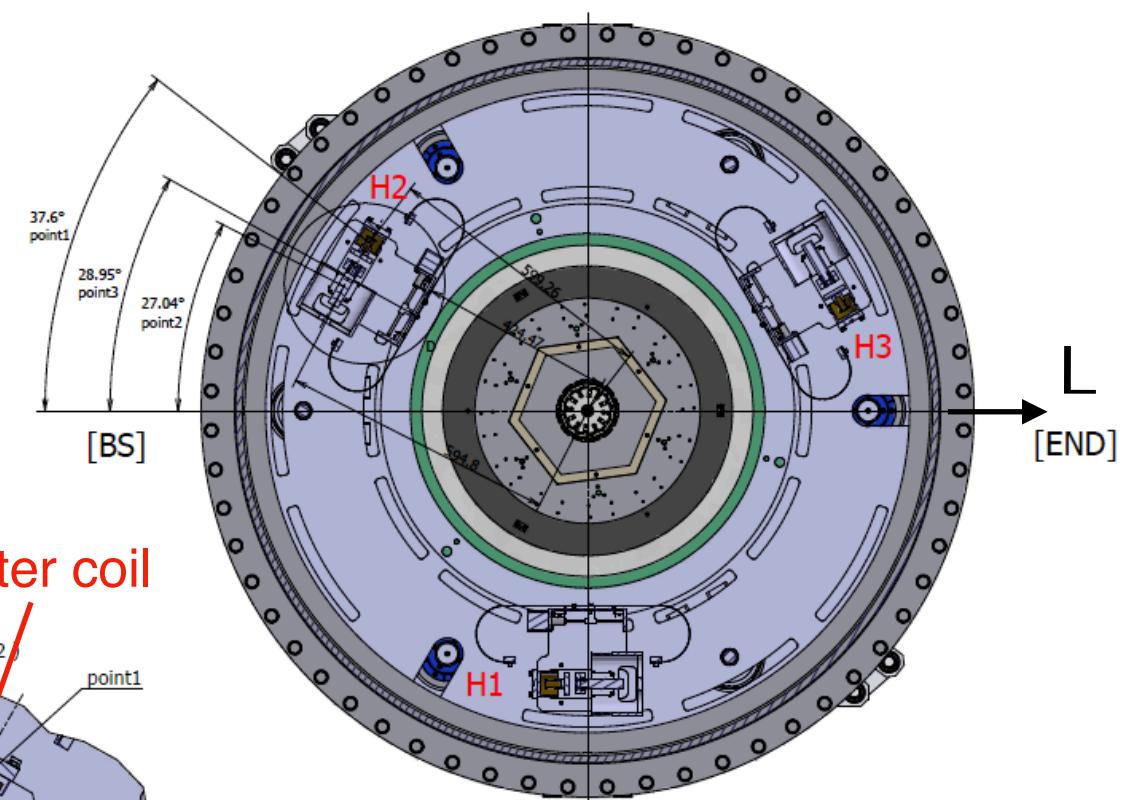


- AAAa

# Top Plate (ITMY case)

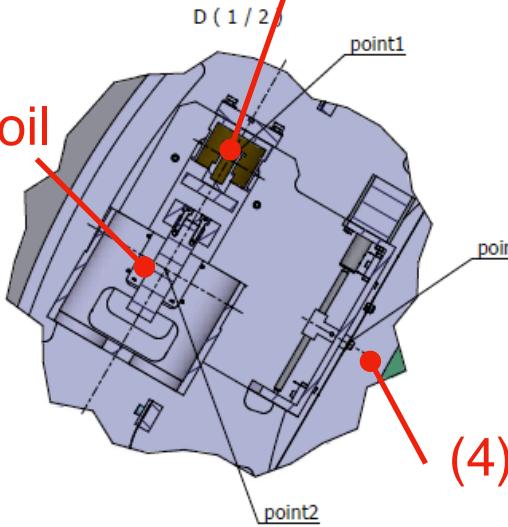


Above the top plate (B)



(1) LVDT emitter coil

(2) LVDT actuation coil



Below the top plate (C)

(4) Fixing point of the Fishing Rod (FR)

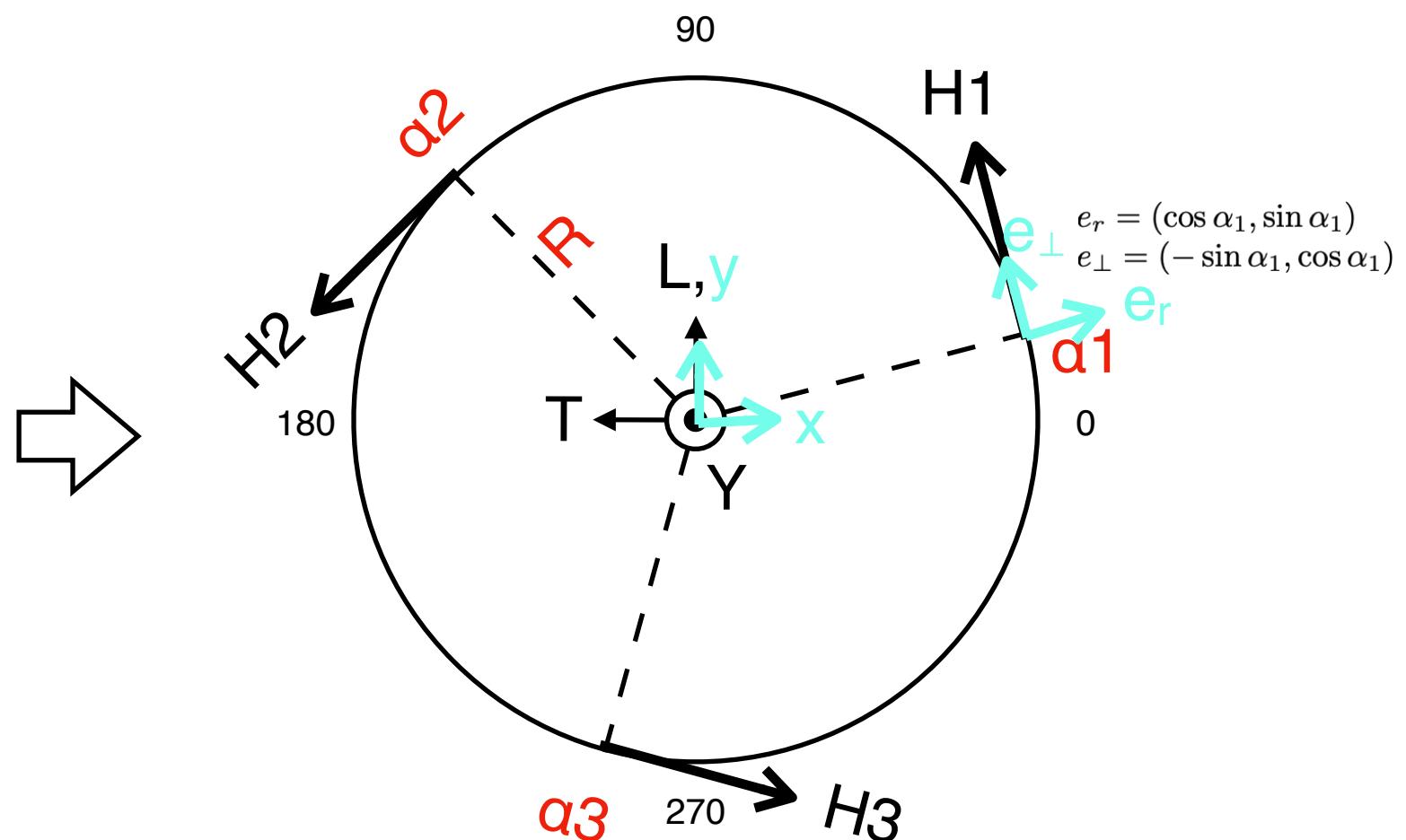
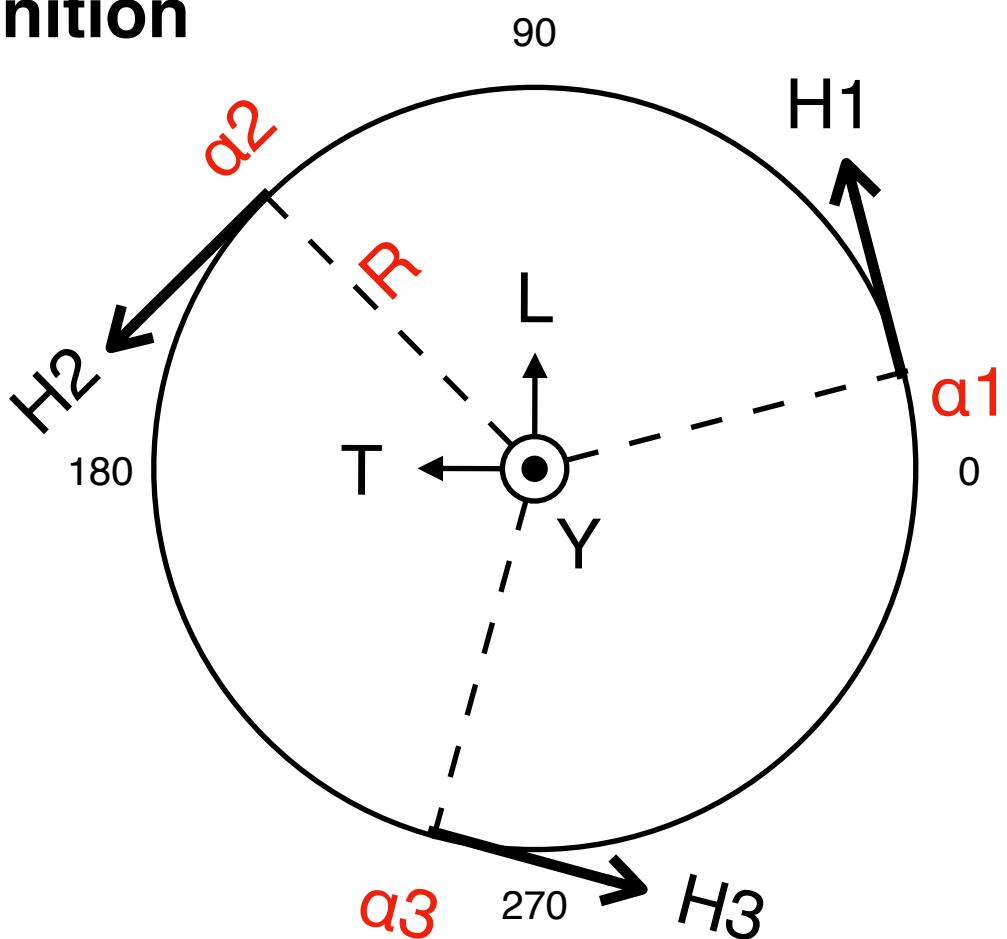
**Four components on the top plate**

EX, IX, EY, IY, BS, SR have different location of the components

# Top Plate / Diagonalization Matrix

JGW-E2012144-v6

## Definition



Sensing matrix : S  
or  
Actuation matrix : D

$$\begin{bmatrix} L \\ T \\ Y \end{bmatrix} = \begin{bmatrix} \cos \alpha_1 & \sin \alpha_1 & R \\ \cos \alpha_2 & \sin \alpha_2 & R \\ \cos \alpha_3 & \sin \alpha_3 & R \end{bmatrix}^{-1} \begin{bmatrix} H_1 \\ H_2 \\ H_3 \end{bmatrix}$$

Consistent with [klog7468](#)

$$\begin{bmatrix} H_1 \\ H_2 \\ H_3 \end{bmatrix} = \begin{bmatrix} -\sin \alpha_1 & \cos \alpha_1 & R \\ -\sin \alpha_2 & \cos \alpha_2 & R \\ -\sin \alpha_3 & \cos \alpha_3 & R \end{bmatrix} \begin{bmatrix} x \\ y \\ Y \end{bmatrix}$$

$$\Updownarrow$$

$$\begin{bmatrix} H_1 \\ H_2 \\ H_3 \end{bmatrix} = \begin{bmatrix} -\sin \alpha_1 & \cos \alpha_1 & R \\ -\sin \alpha_2 & \cos \alpha_2 & R \\ -\sin \alpha_3 & \cos \alpha_3 & R \end{bmatrix} \begin{bmatrix} -T \\ L \\ Y \end{bmatrix}$$

$$\Updownarrow$$

$$\begin{bmatrix} H_1 \\ H_2 \\ H_3 \end{bmatrix} = \begin{bmatrix} \cos \alpha_1 & \sin \alpha_1 & R \\ \cos \alpha_2 & \sin \alpha_2 & R \\ \cos \alpha_3 & \sin \alpha_3 & R \end{bmatrix} \begin{bmatrix} L \\ T \\ Y \end{bmatrix}$$

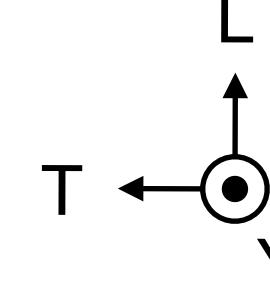
# Top Plate / The location of ITMX

JGW-E2012144-v6

$a=(\text{point1}, \text{point2}, \text{point3})$

LVDT	LVDT	FR
Emit. Coil	Act. Coil	Fix point

[END]



$a_3 = a_2 - 120$

H3

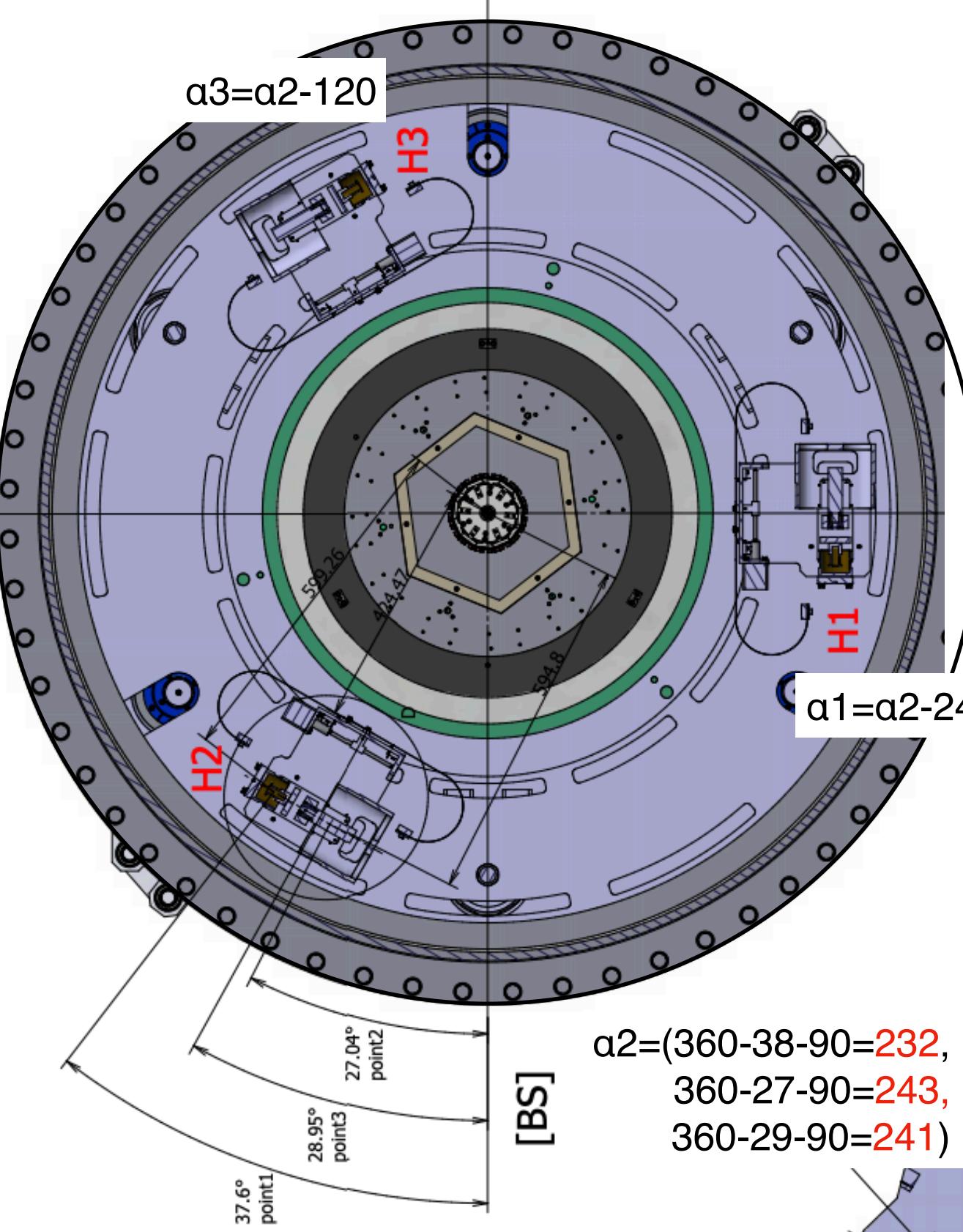
$a_1 = a_2 - 240$

H2

H1

C-C (1:5)

B-B (1:5)



$a_3 = 45 + 90 = 135$

$R = 0.478$

$a_1 = a_3 - 120$

H1

$a_2 = a_3 + 120$

H2

[END]

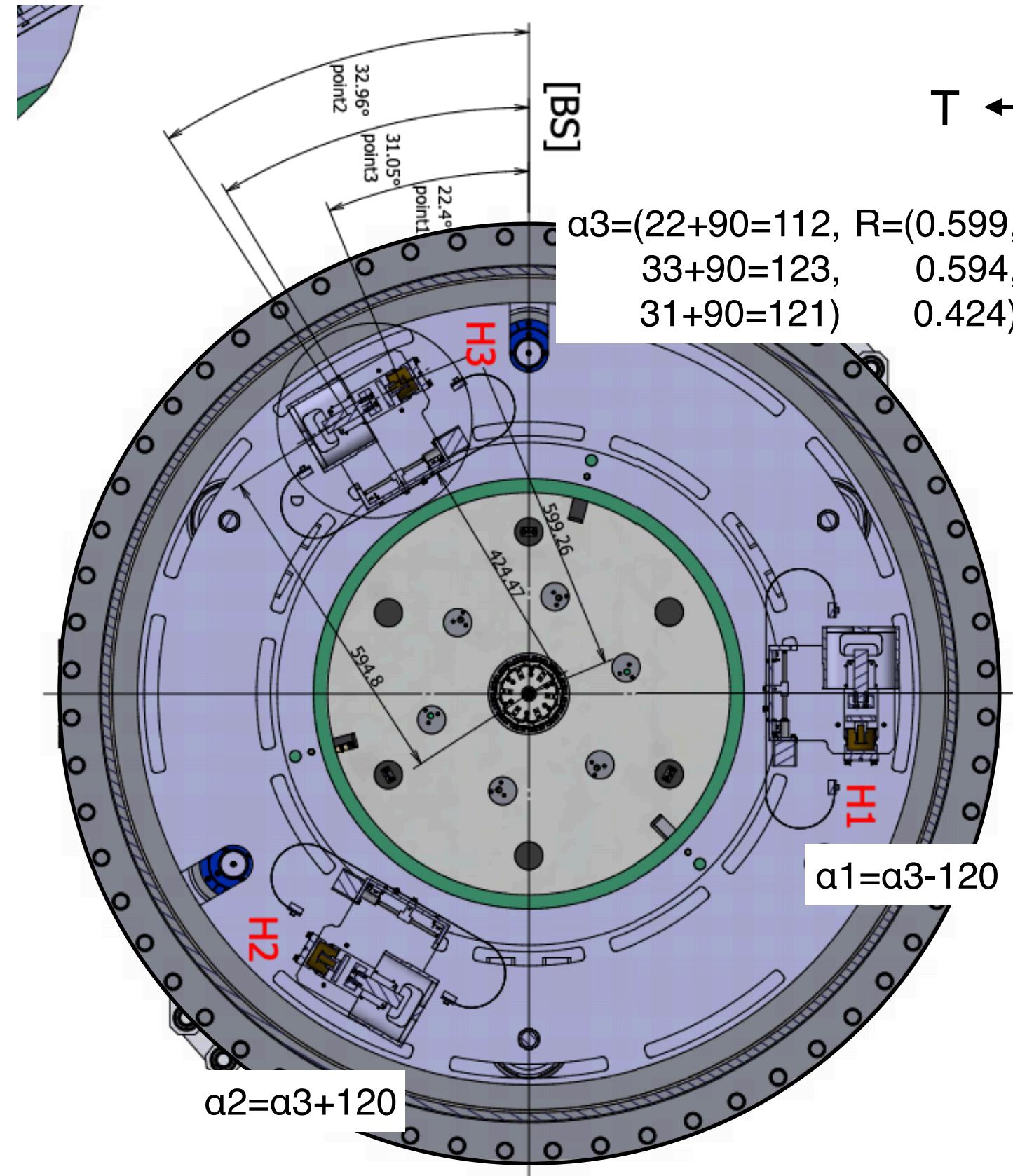
[BS]

$a = \text{point1}$

Accelerometer

# Top Plate / The location of ETMX

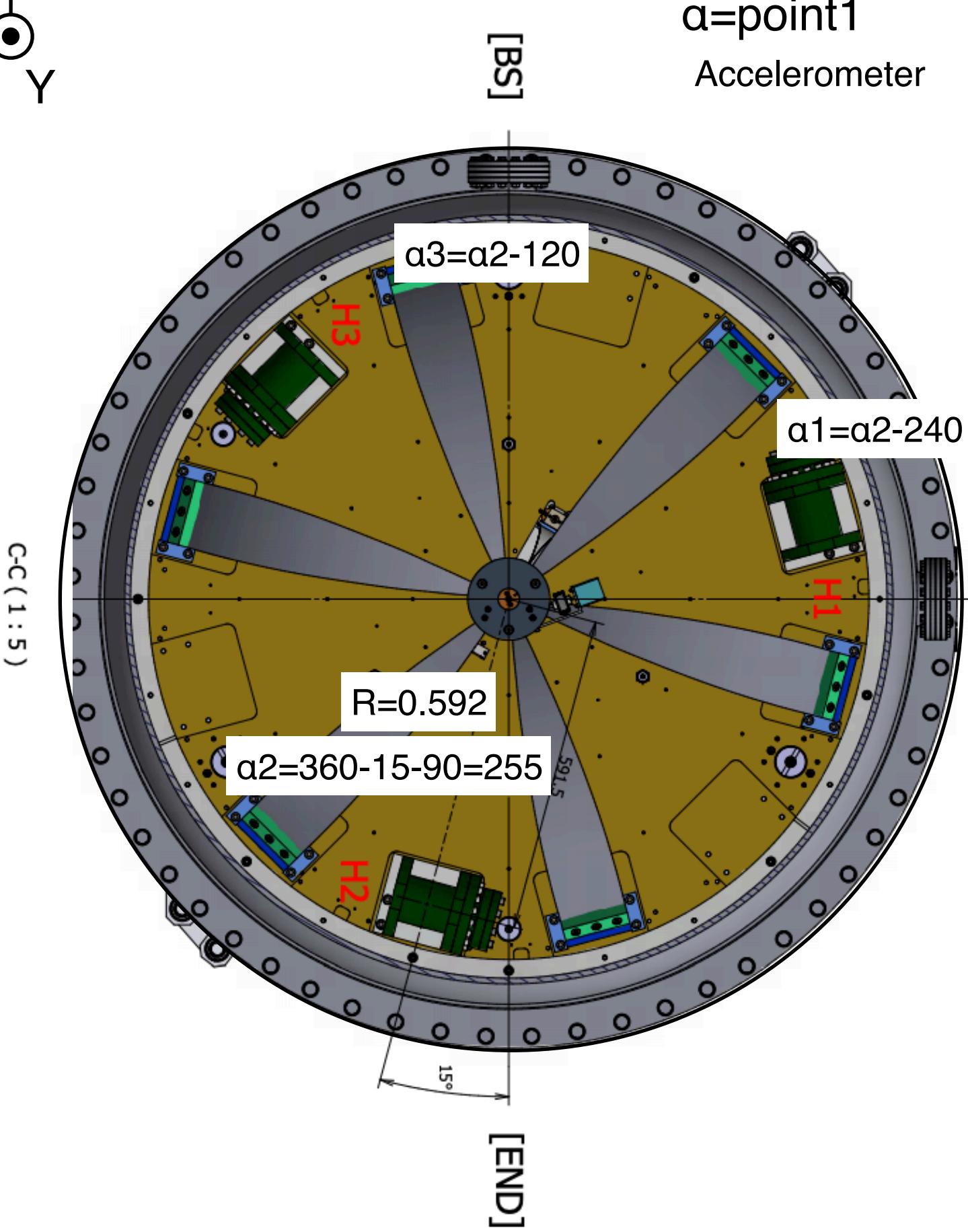
JGW-E2012144-v6



$a=(\text{point1}, \text{point2}, \text{point3})$

LVDT	LVDT	FR
Emit. Coil	Act. Coil	Fix point

[END]



# Top Plate / The location of ITMY

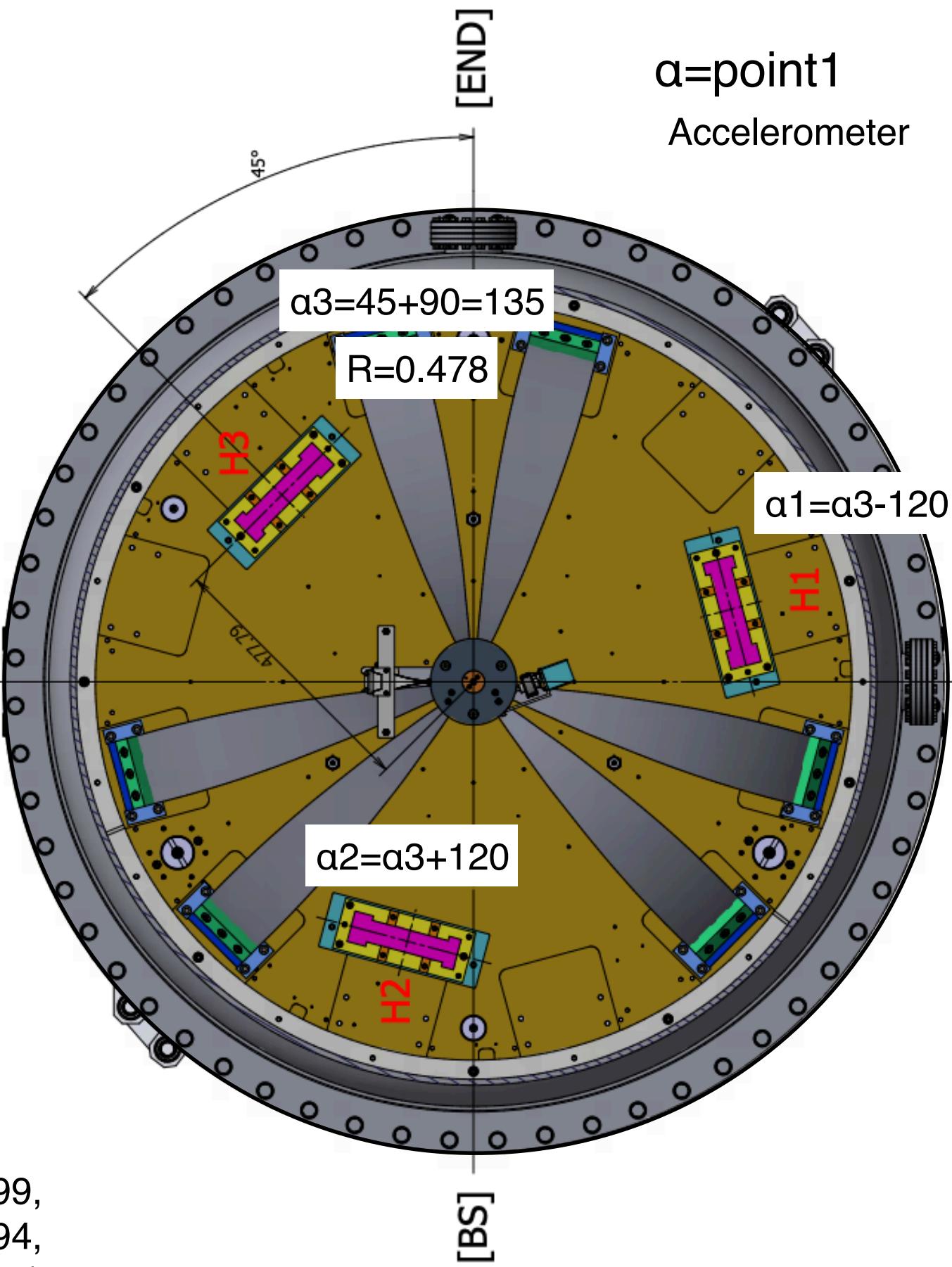
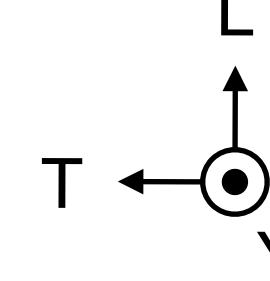
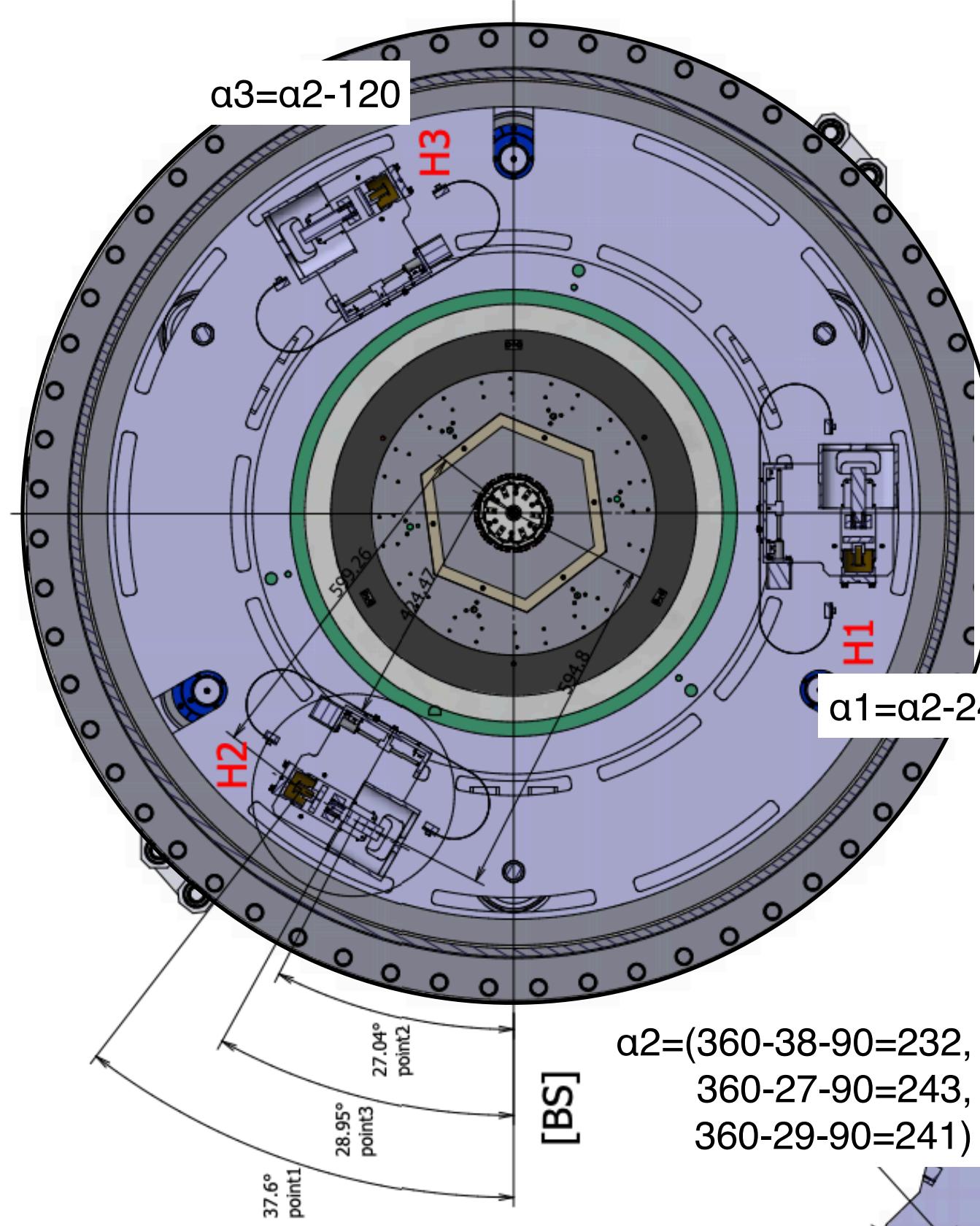
Same as the ITMX

JGW-E2012144-v6

$a=(\text{point1}, \text{point2}, \text{point3})$

LVDT LVDT FR  
Emit. Coil Act. Coil Fix point

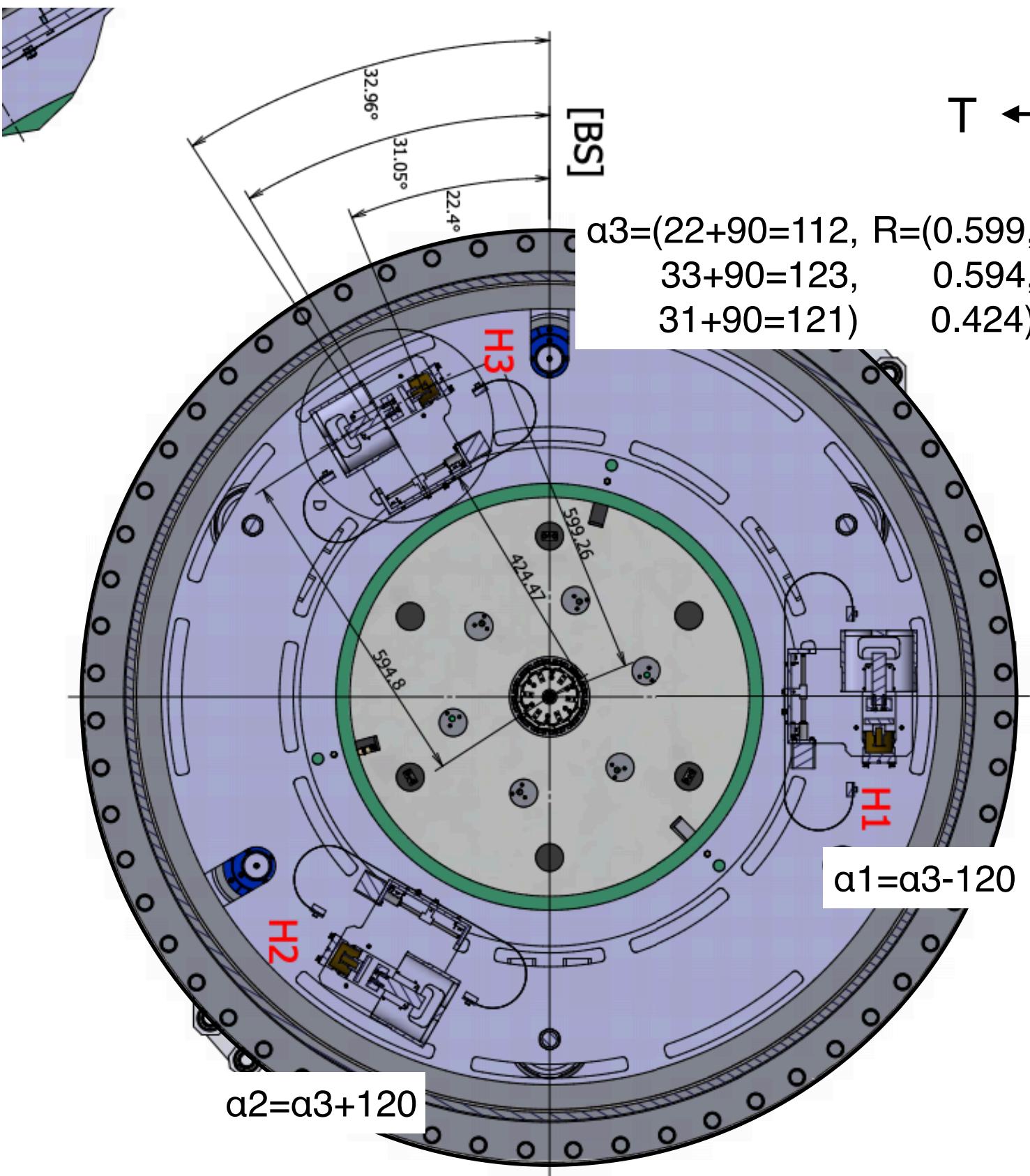
[END]



$a=\text{point1}$   
Accelerometer

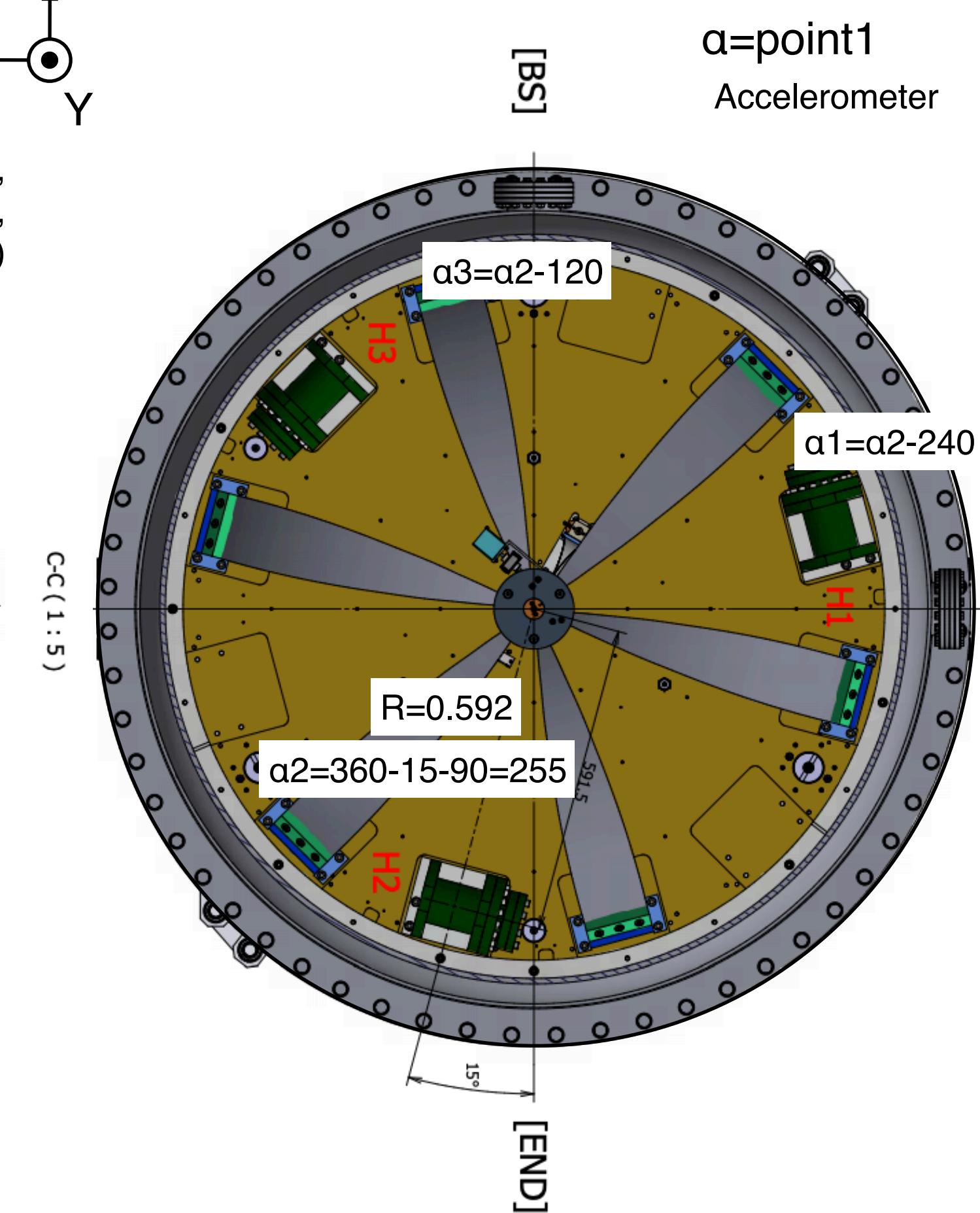
# Top Plate / The location of ETMY

Same as the ETMX W-E2012144-v6



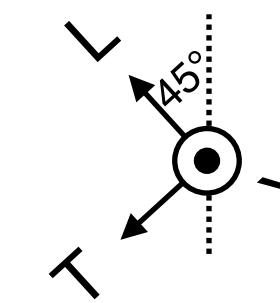
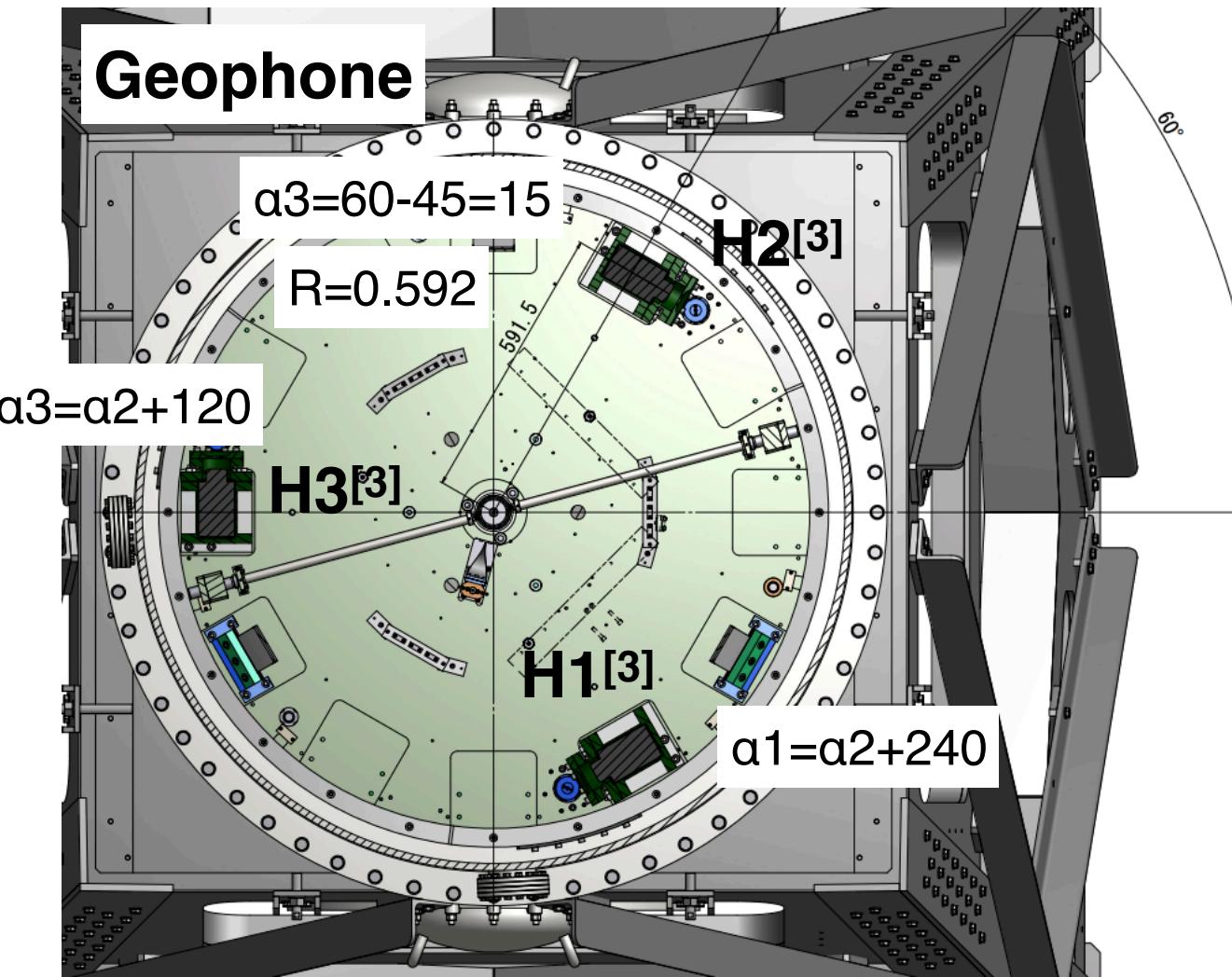
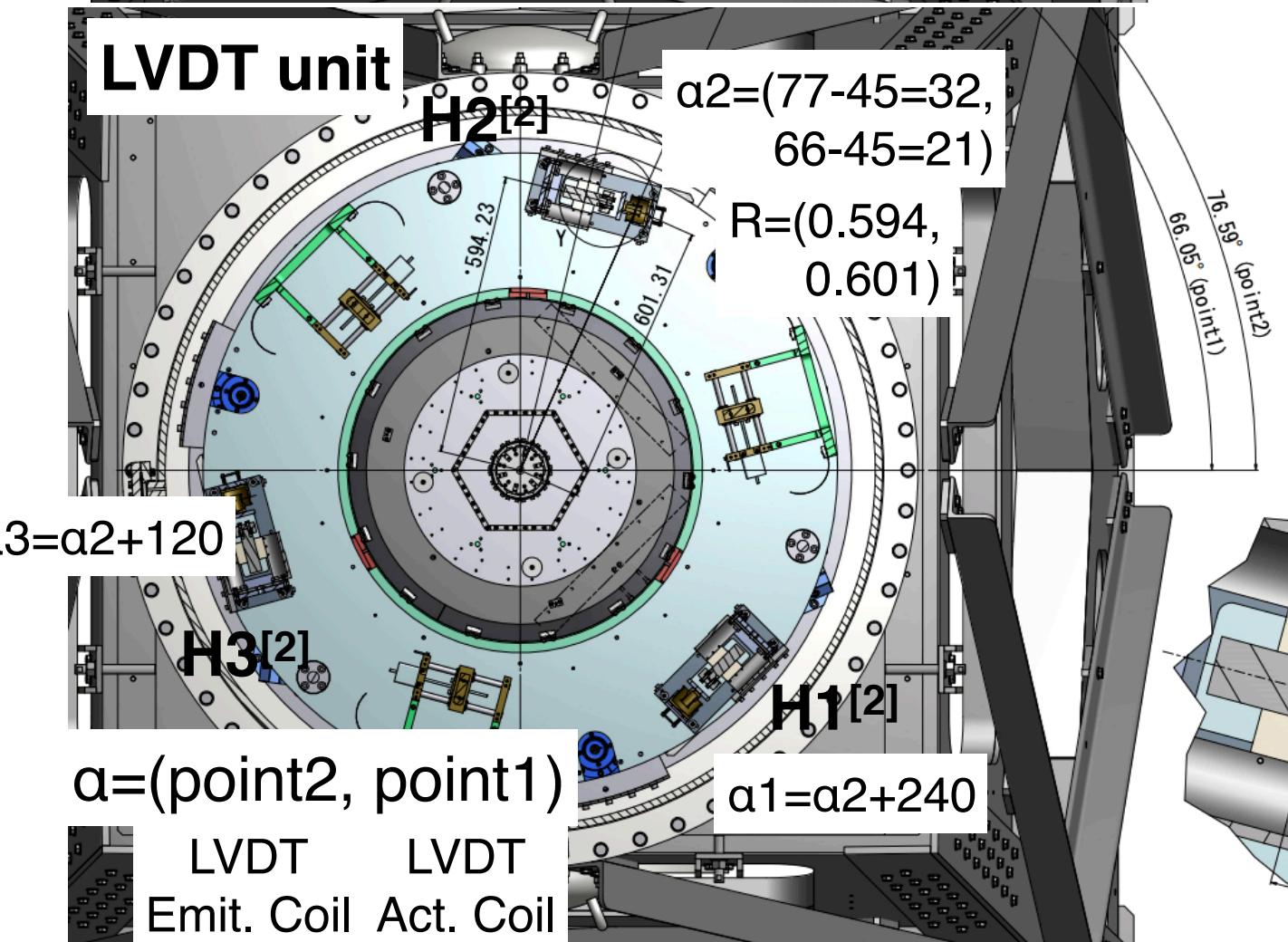
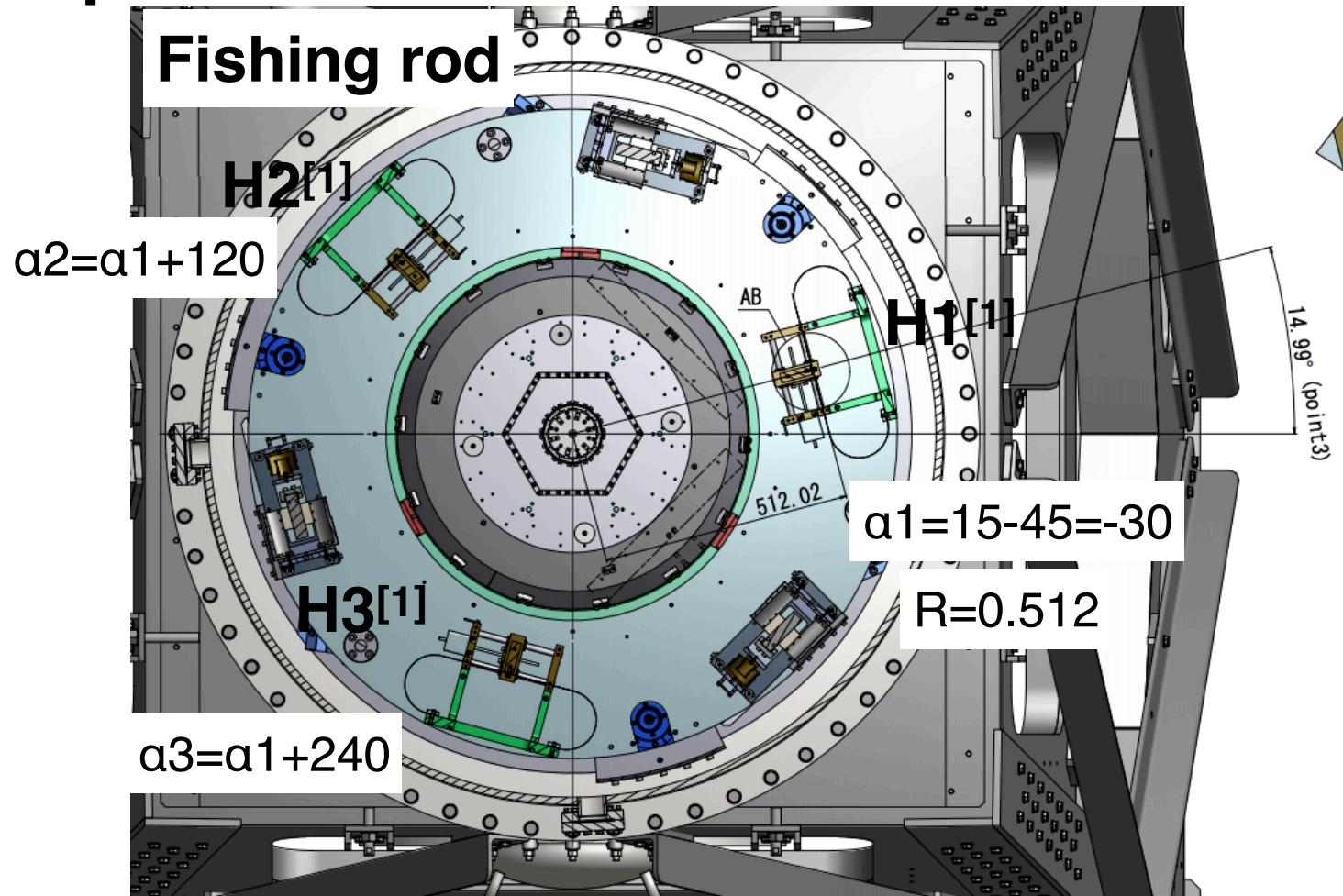
$a=(\text{point1}, \text{point2}, \text{point3})$

LVDT LVDT FR  
Emit. Coil Act. Coil Fix point



# Top Plate / The location of BS

JGW-E2012144-v6



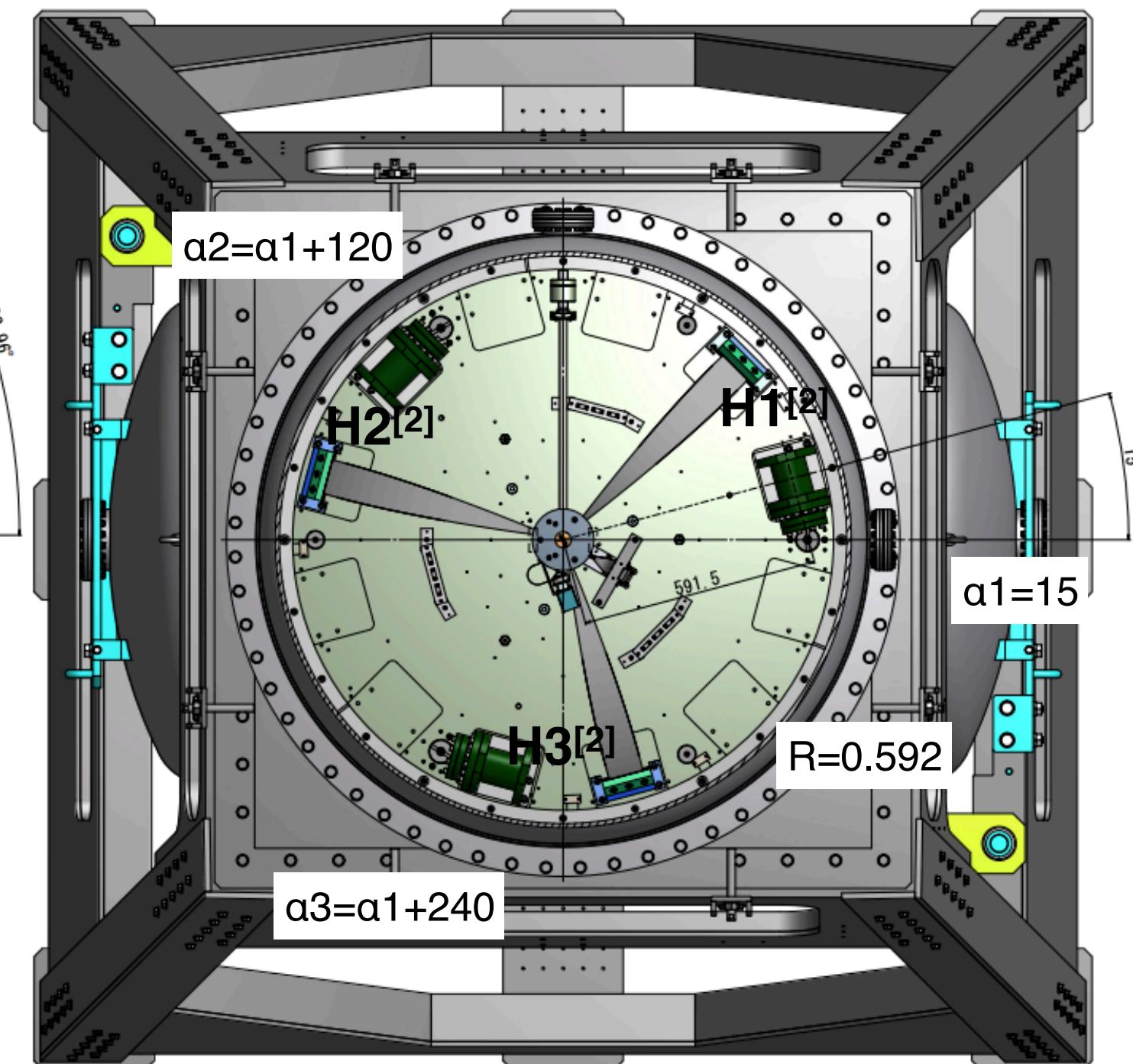
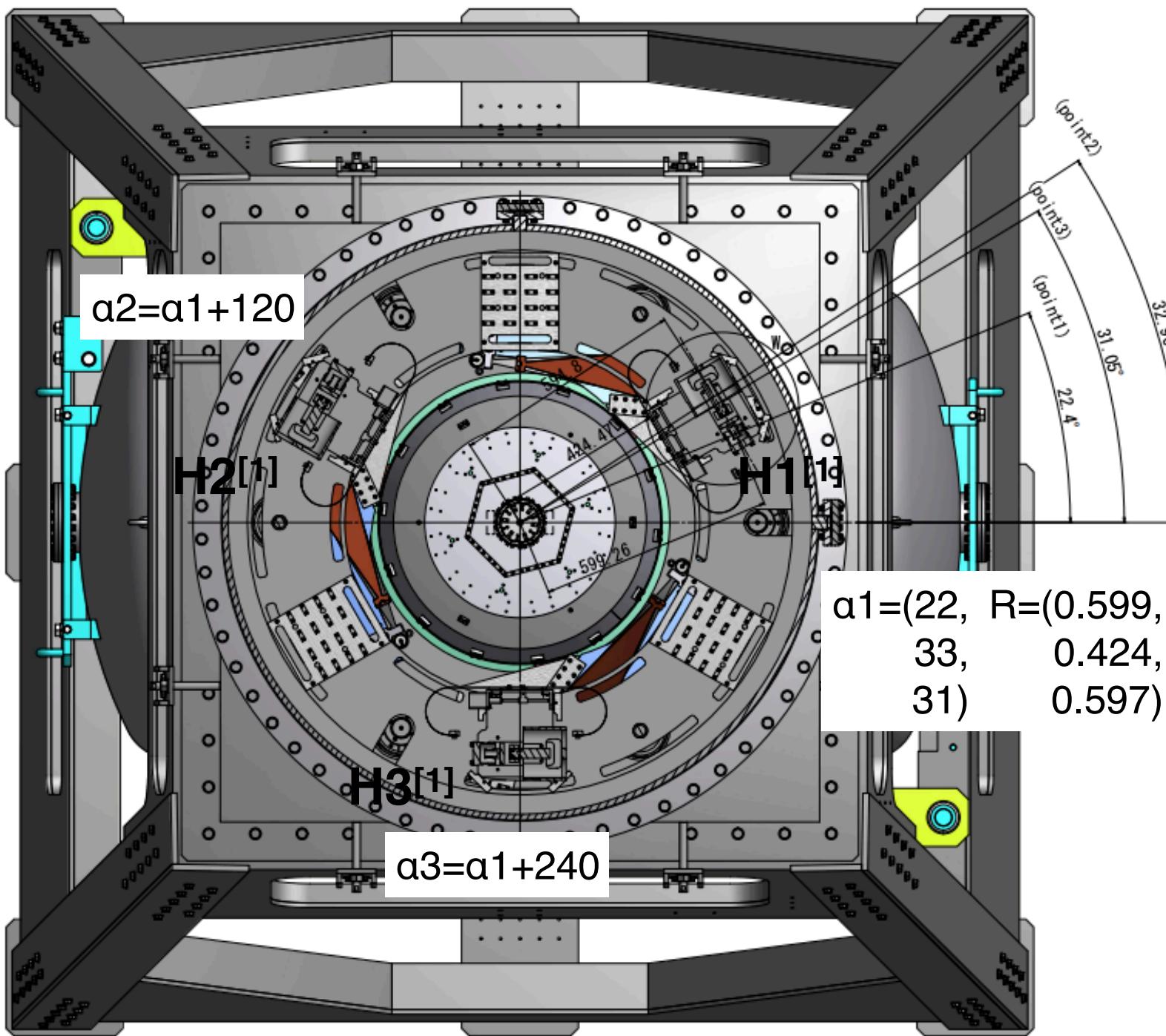
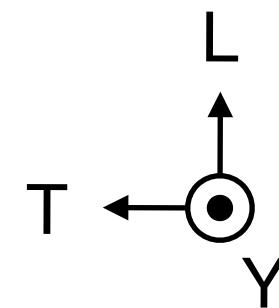
- [1] I'm not sure the label names for FRs.
- [2] I'm not sure the label names for LVDT.
- [3] I'm not sure the label names for geophone.

# Top Plate / The location of SR

JGW-E2012144-v6

$a=(\text{point1}, \text{point2}, \text{point3})$

LVDT	LVDT	FR
Emit. Coil	Act. Coil	Fix point



[1] Label is referred from Fabian's email "SR IP fishing rods transformation formulas with correct naming" in 2020/10/21.

# Top Plate / Parameters

JGW-E2012144-v6

## (1) LVDT emitter coils

	$\alpha_1$ [deg]	$\alpha_2$ [deg]	$\alpha_3$ [deg]	R [m]	Reference	Check
ETMX	-8	232	112	0.595	<a href="#">JGW-D2012142-v1 (EX)</a>	三代 佐藤
ITMX	-8	232	112	0.595	<a href="#">JGW-D2012142-v1 (IX)</a>	三代 佐藤
ETMY	-8	232	112	0.595	<a href="#">JGW-D2012142-v1 (EY)</a>	三代 佐藤
ITMY	-8	232	112	0.595	<a href="#">JGW-D2012142-v1 (IY)</a>	三代 佐藤
BS	32	272	152	0.594	<a href="#">JGW-D1605092-v4</a>	三代
SR2	22	142	262	0.579	<a href="#">JGW-D1707077-v7</a>	三代
SR3	22	142	262	0.579	<a href="#">JGW-D1707077-v7</a>	三代
SRM	22	142	262	0.579	<a href="#">JGW-D1707077-v7</a>	三代

## (2) LVDT actuator coils

	$\alpha_1$ [deg]	$\alpha_2$ [deg]	$\alpha_3$ [deg]	R [m]	Reference	Check
ETMX	3	243	123	0.599	<a href="#">JGW-D2012142-v1 (EX)</a>	三代 佐藤
ITMX	3	243	123	0.599	<a href="#">JGW-D2012142-v1 (IX)</a>	三代 佐藤
ETMY	3	243	123	0.599	<a href="#">JGW-D2012142-v1 (EY)</a>	三代 佐藤
ITMY	3	243	123	0.599	<a href="#">JGW-D2012142-v1 (IY)</a>	三代 佐藤
BS	21	261	141	0.601	<a href="#">JGW-D1605092-v4</a>	三代
SR2	33	273	153	0.599	<a href="#">JGW-D1707077-v7</a>	三代
SR3	33	273	153	0.599	<a href="#">JGW-D1707077-v7</a>	三代
SRM	33	273	153	0.599	<a href="#">JGW-D1707077-v7</a>	三代

## (3) Accelerometer

	$\alpha_1$ [deg]	$\alpha_2$ [deg]	$\alpha_3$ [deg]	R [m]	Reference	Check
ETMX	15	255	135	0.592	<a href="#">JGW-D2012142-v1 (EX)</a> [1]	三代 佐藤
ITMX	15	255	135	0.478	<a href="#">JGW-D2012142-v1 (IX)</a>	三代 佐藤
ETMY	15	255	135	0.592	<a href="#">JGW-D2012142-v1 (EY)</a> [1]	三代 佐藤
ITMY	15	255	135	0.478	<a href="#">JGW-D2012142-v1 (IY)</a>	三代 佐藤
BS	15	255	135	0.592	<a href="#">JGW-D1605092-v4</a>	三代
SR2	15	255	135	0.592	<a href="#">JGW-D1707077-v7</a>	三代
SR3	15	255	135	0.592	<a href="#">JGW-D1707077-v7</a>	三代
SRM	15	255	135	0.592	<a href="#">JGW-D1707077-v7</a>	三代

## (4) Fixing point of the FR

	$\alpha_1$ [deg]	$\alpha_2$ [deg]	$\alpha_3$ [deg]	R [m]	Reference	Check
ETMX	1	241	121	0.424	<a href="#">JGW-D2012142-v1 (EX)</a>	三代 佐藤
ITMX	1	241	121	0.424	<a href="#">JGW-D2012142-v1 (IX)</a>	三代 佐藤
ETMY	1	241	121	0.424	<a href="#">JGW-D2012142-v1 (EY)</a>	三代 佐藤
ITMY	1	241	121	0.424	<a href="#">JGW-D2012142-v1 (IY)</a>	三代 佐藤
BS	-30	210	90	0.512	<a href="#">JGW-D1605092-v4</a>	三代
SR2	31	271	151	0.424	<a href="#">JGW-D1707077-v7</a>	三代
SR3	31	271	151	0.424	<a href="#">JGW-D1707077-v7</a>	三代
SRM	31	271	151	0.424	<a href="#">JGW-D1707077-v7</a>	三代

[1] ETMs used a geophone for O3. ETMs will use new LVDT accelerometer which is installed as same as the IX and IY, according to Sato-san.

# Intermediate Mass

JGW-E2012144-v6

# Geometric Anti-Spring

JGW-E2012144-v6

# Bottom Filter

JGW-E2012144-v6

# Marionetta Mass

JGW-E2012144-v6

# Optical Lever

JGW-E2012144-v6

## Manual

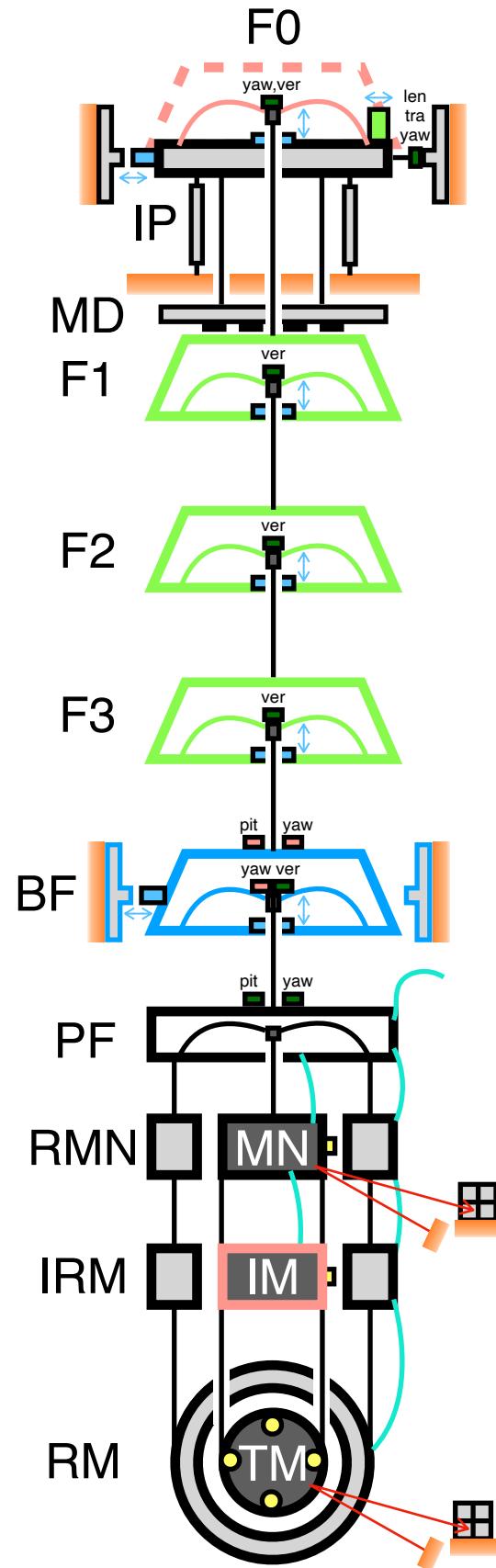
- Installation manual of OpLev : [JGW-T1707228-v6](#)
- Length Sensing : [JGW-T1605788-v11](#)
- OpLev setup for SR3 : [JGW-G1808874-v1](#)

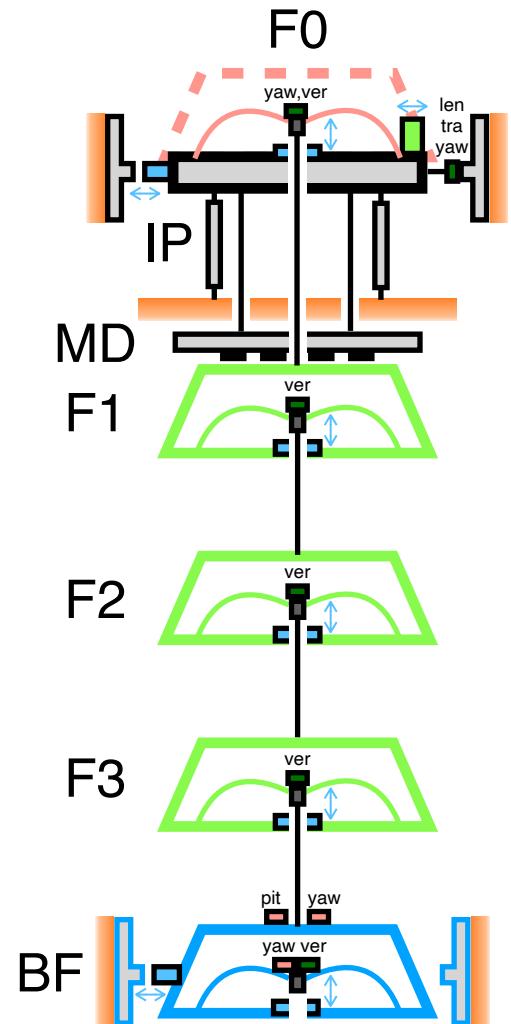
## Sketch of the OpLev table

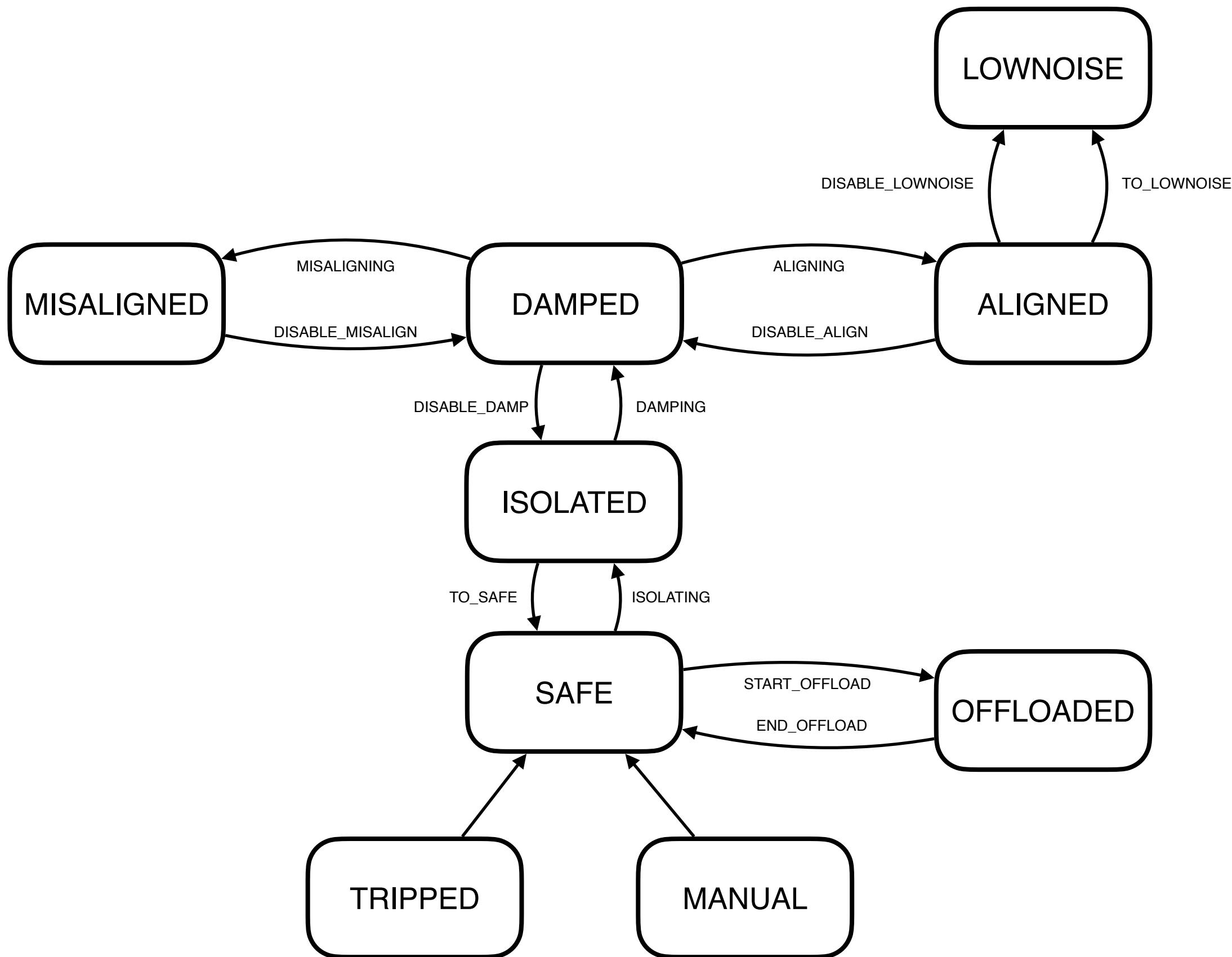
- PRM : [JGW-D1909596-v2](#)
- PR2 : [JGW-D1605877-v2](#)
- PR3 : [JGW-D1605867-v4](#)
- BS : [JGW-D1909928-v1 \(Old?\)](#)
- SRs : [JGW-D1809594-v3](#)
- TMs : [JGW-D1707064-v2](#)
- MNs : ???

# Procedure

JGW-E2012144-v6



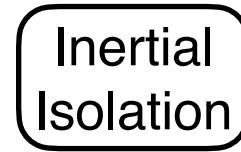




# Strategy for the Vibration Isolation

JGW-E2012144-v6

Inertial  
Isolation



[F. Matichard. et. al \(2015\)](#)

[S.Braccini, et. al \(2005\)](#)

