

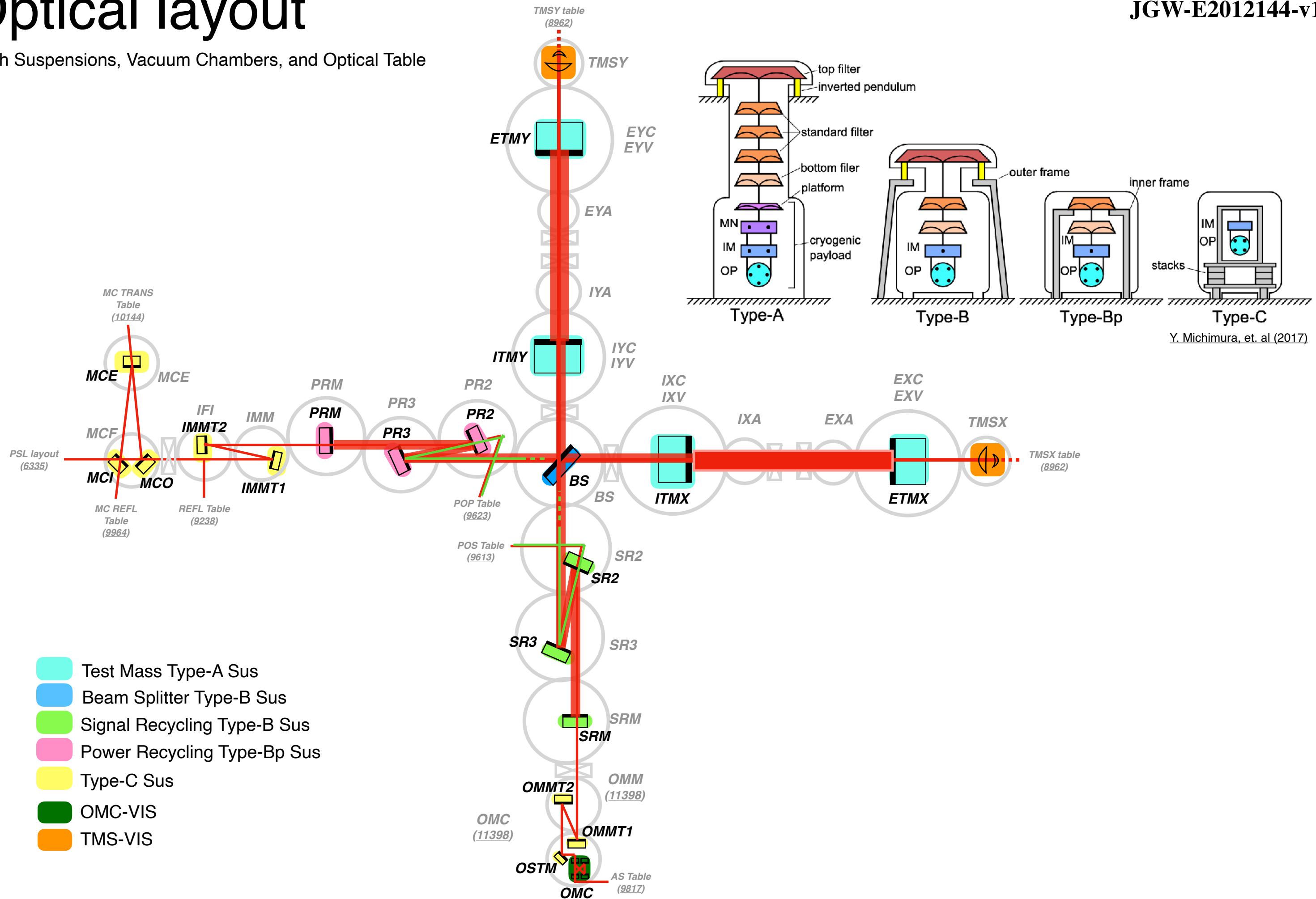
All of the
Vibration Isolation System
in KAGRA

JGW-E2012144-v10

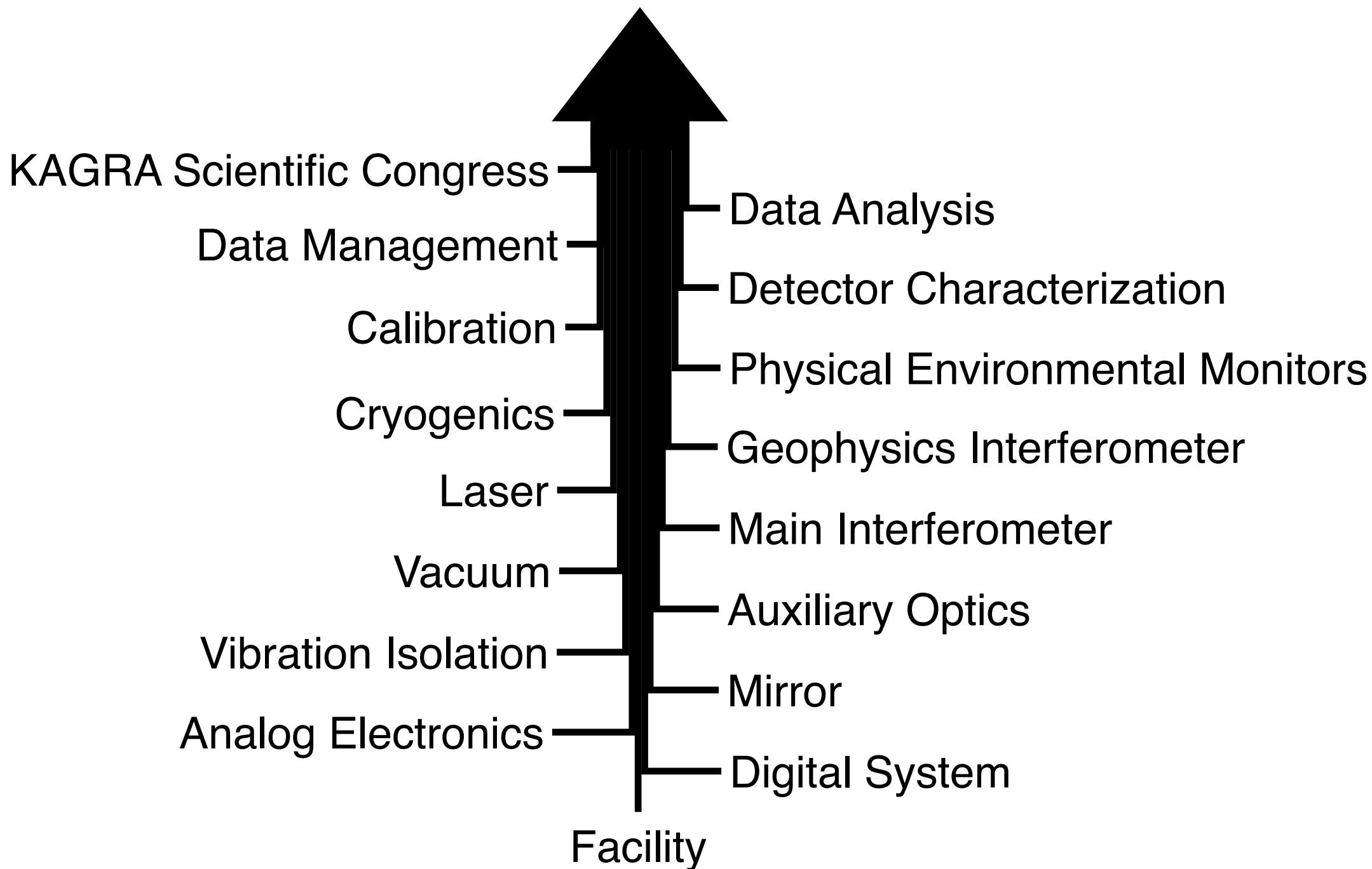
Optical layout

JGW-E2012144-v10

with Suspensions, Vacuum Chambers, and Optical Table

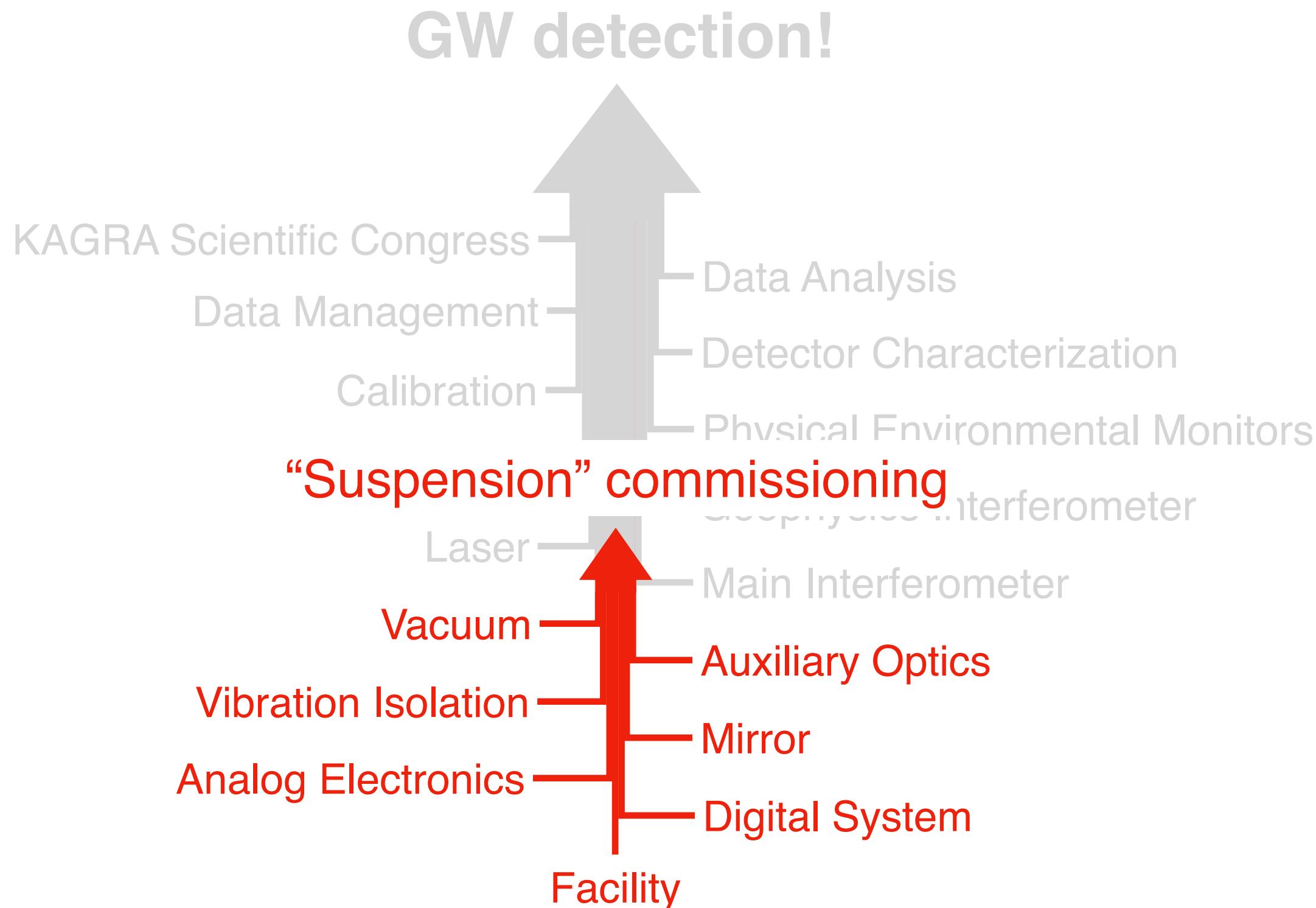


GW detection!



Commissioning is ...

JGW-E2012144-v10

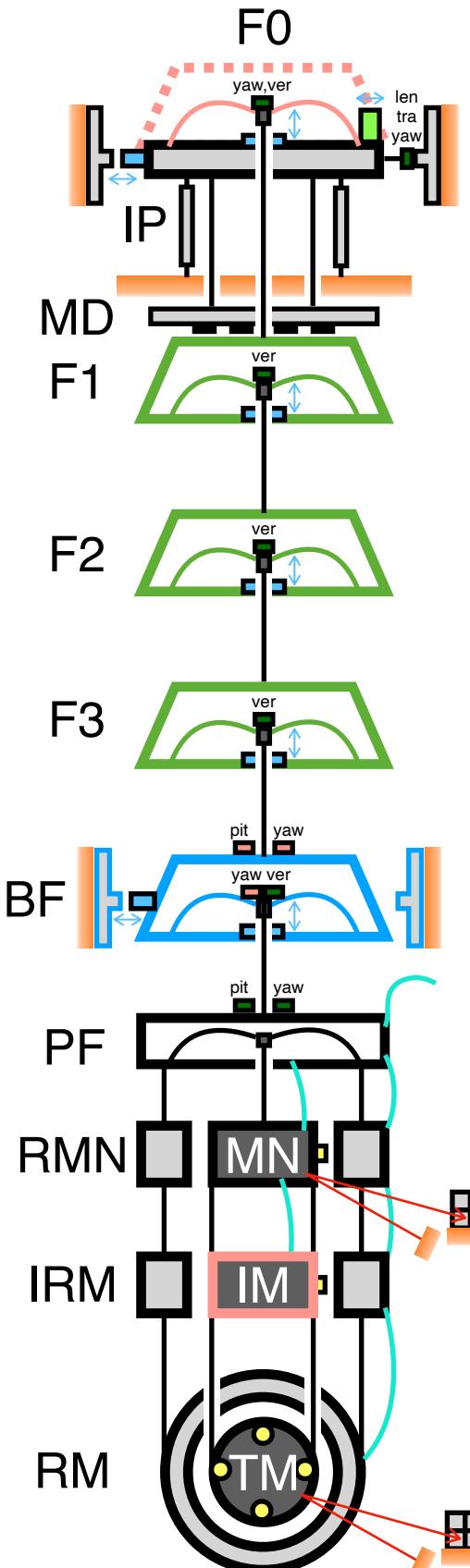


[KAGRA organization chart](#)

Suspensions

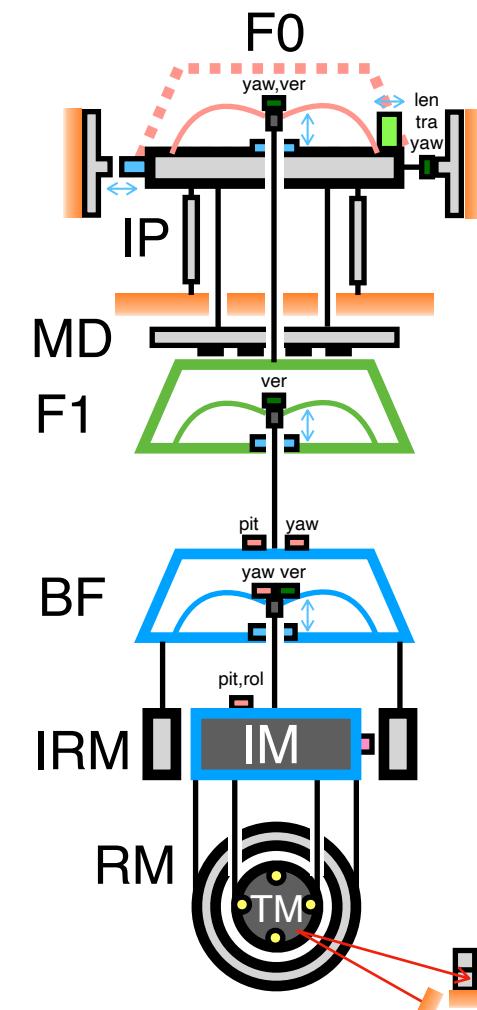
JGW-E2012144-v10

with sensors and actuators

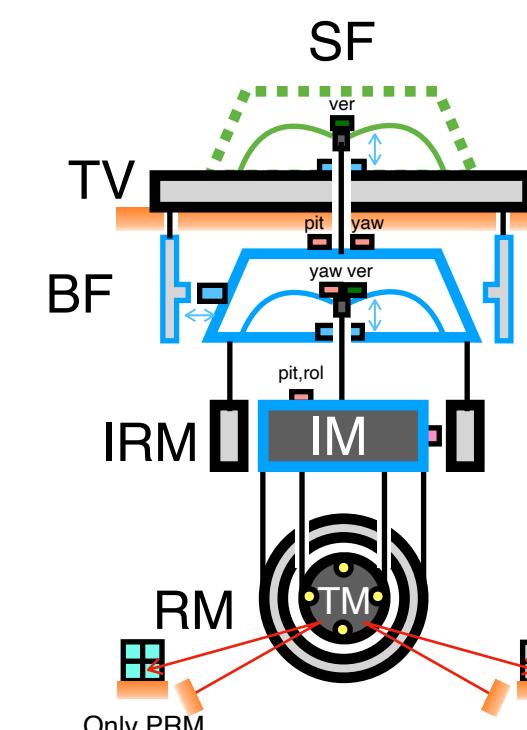


Type-A

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



Type-B



Type-Bp

- 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)

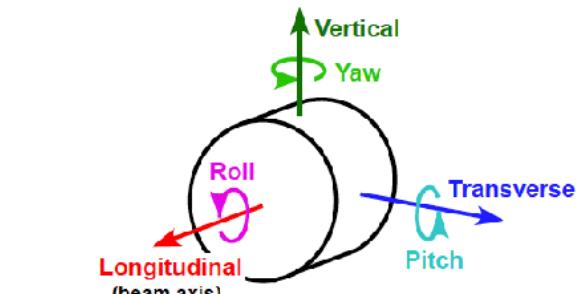
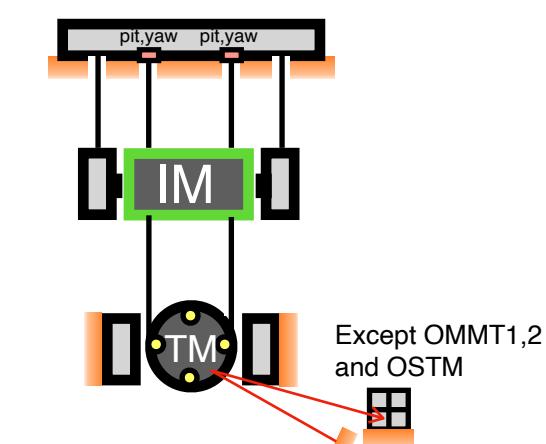


Figure 2.7: Definition of the coordinate system.

from T. Sekiguchi PhD thesis



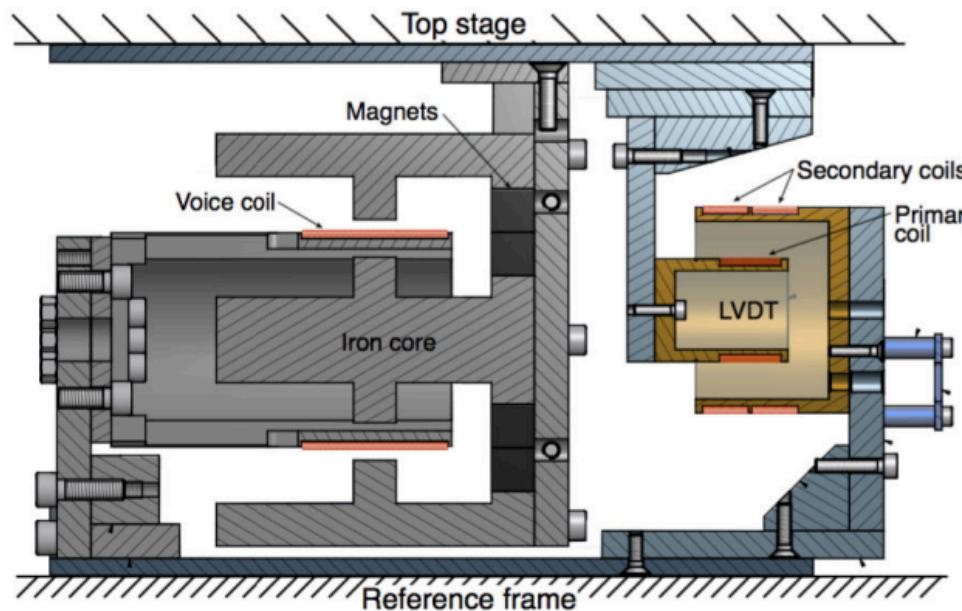
Type-C

Calibration

JGW-E2012144-v10



IP-LVDT



CAD view of the LVDT and VoCo

Fig. 1.22 from Joris's PhD thesis

GAS-LVDT

No picture?

BF-LVDT

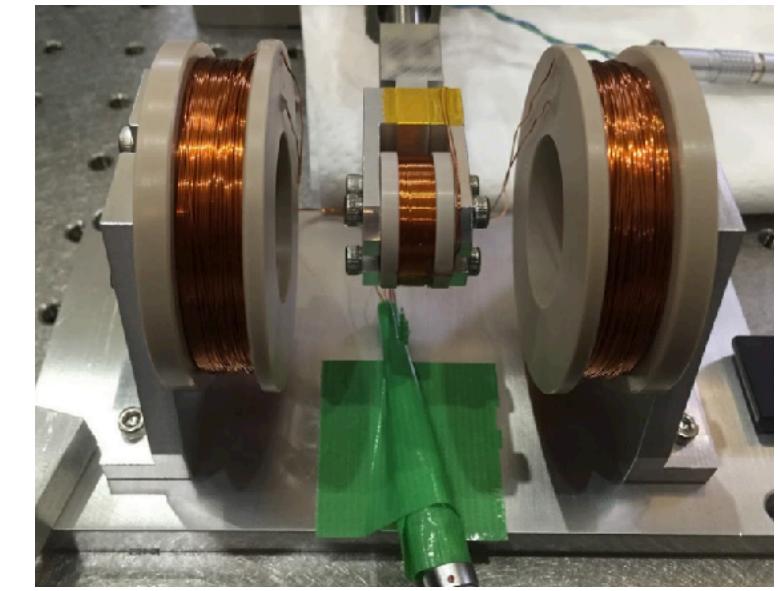
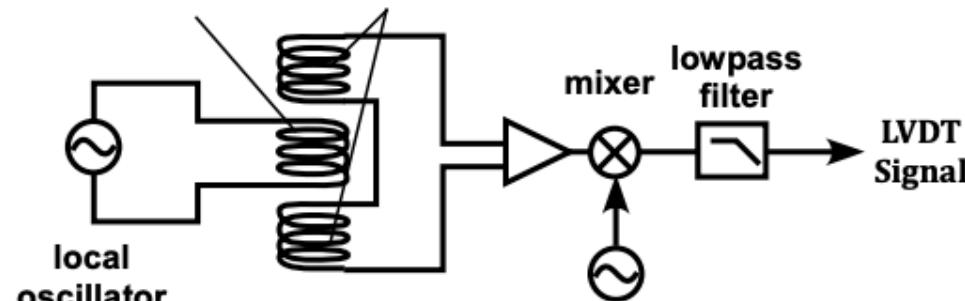


Fig. 6.4 from Yoshinori's PhD thesis

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

Schematic view of LVDT

Fig. 6.5 from Takanori's PhD thesis

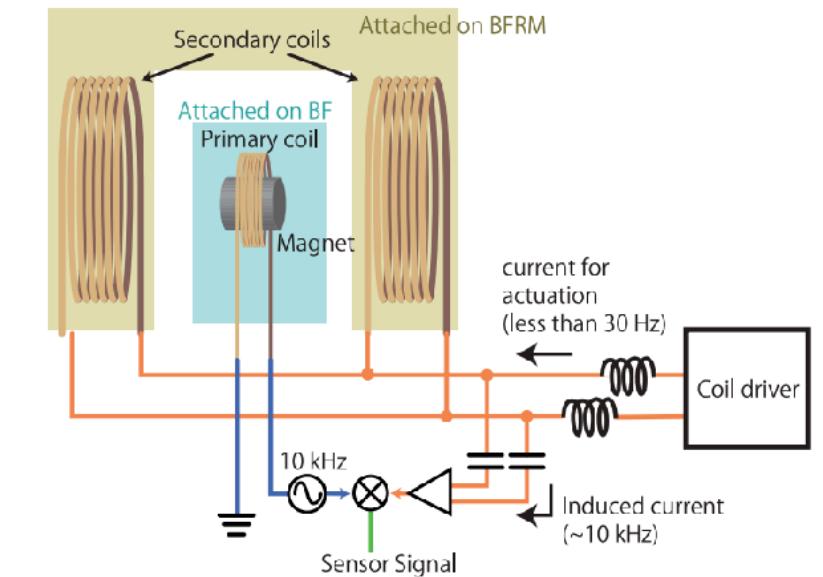
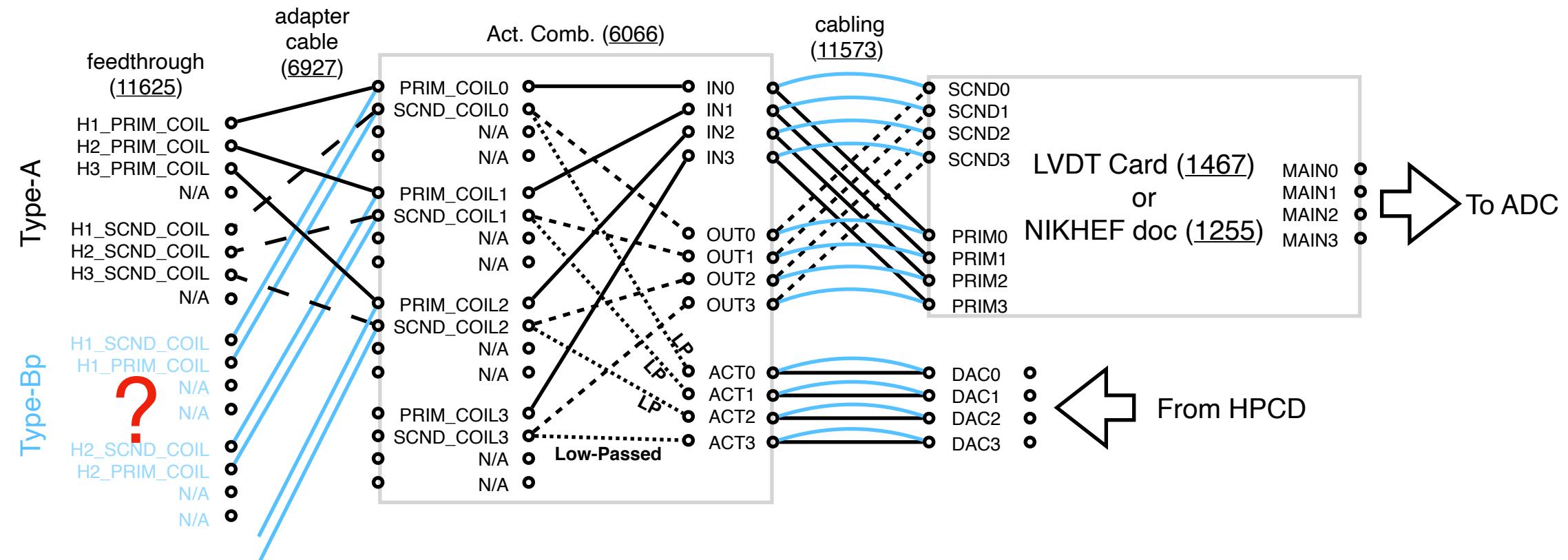
Same as the
IP-LVDT?

Fig. 5 Y Akiyama et.al (2019)

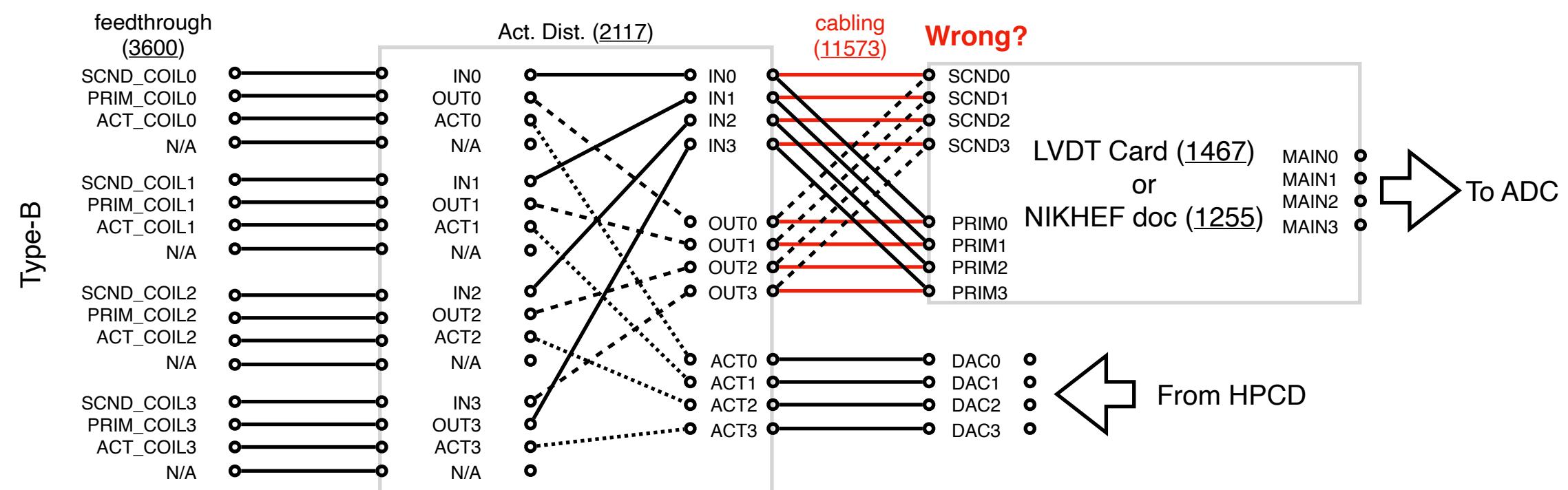
LVDT connections in O3 (in the H case)

JGW-E2012144-v10

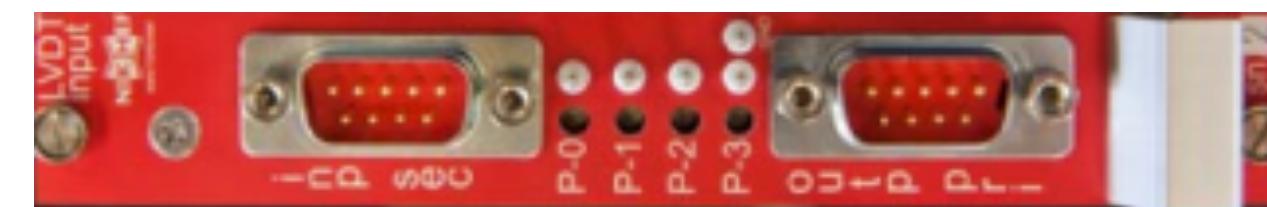
BF-LVDT

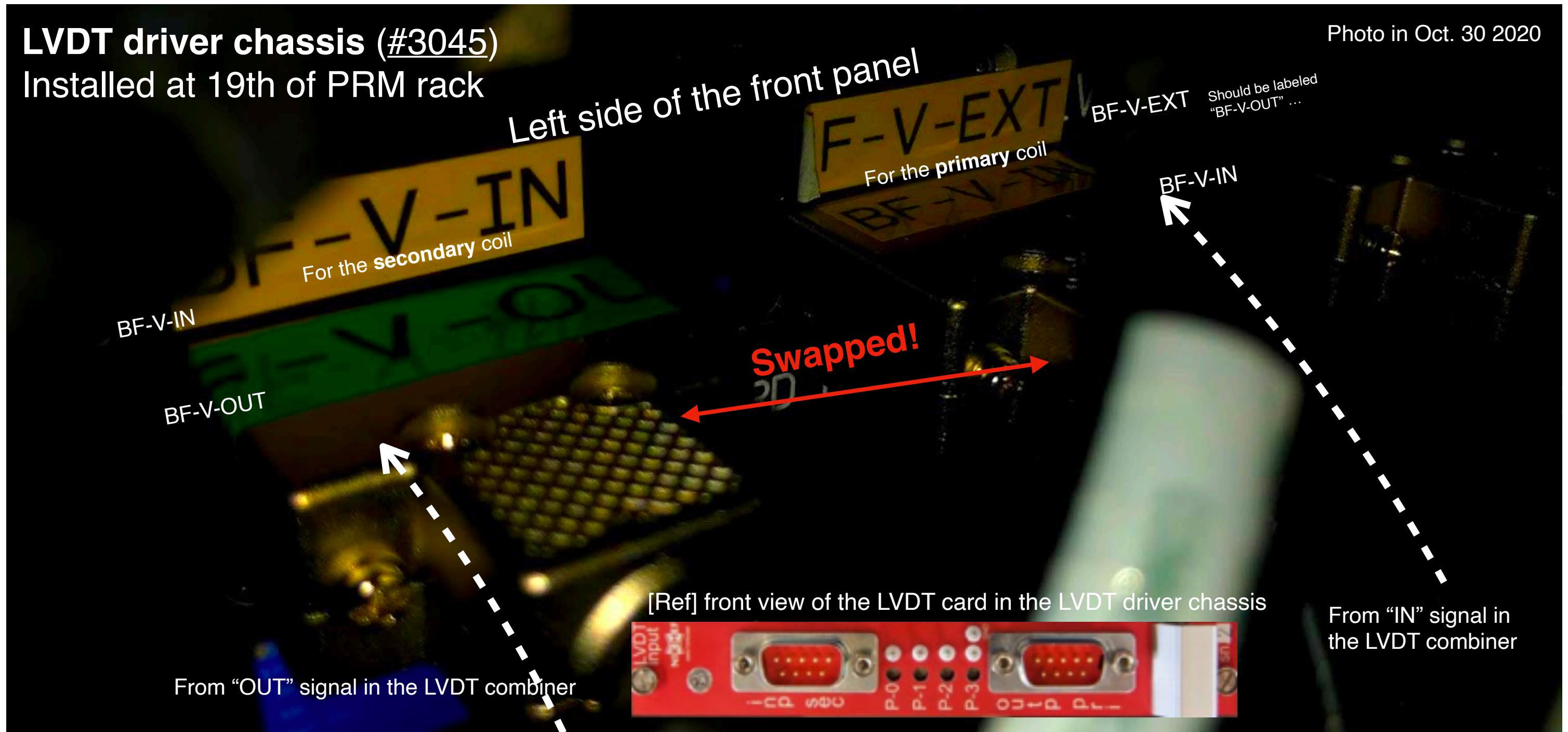


GAS/IP-LVDT



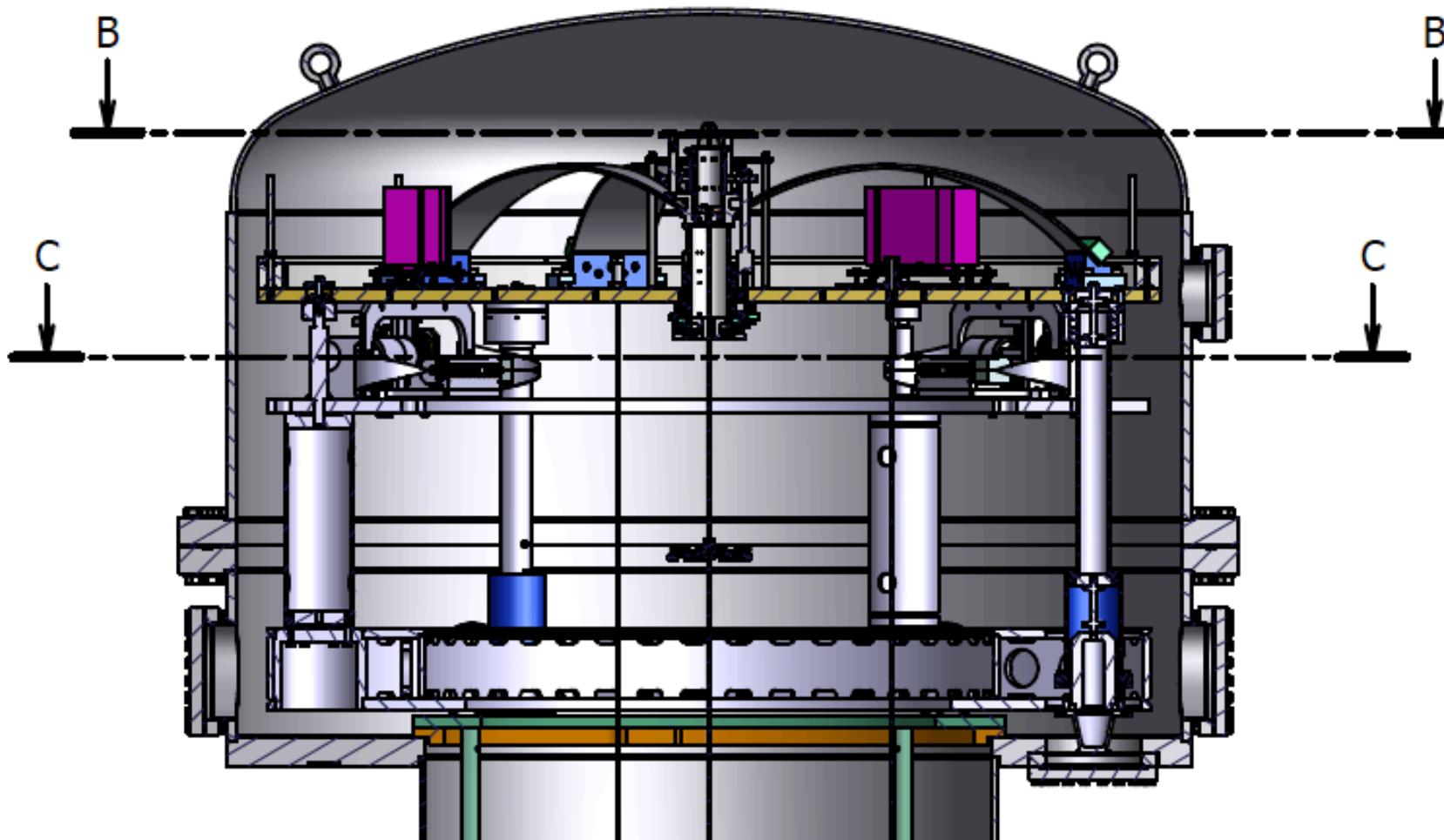
[Note] In the TypeB case, at the pin assignment at the feedthrough, the secondary and the primary signal have been swapped out. This means that cabling style like Type-A would be correct. In other word, "IN" signal labeled in both Combiner and Distributor should be connected to the "right" side connector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





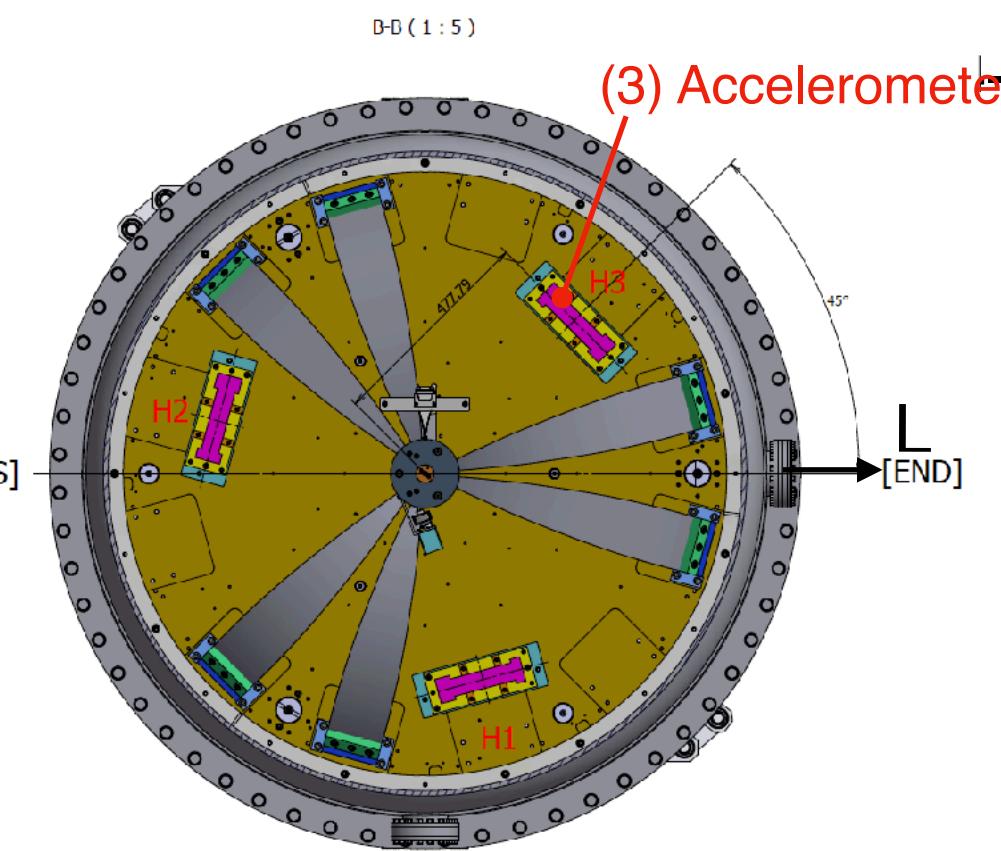
- AAAa

Top Plate (ITMY case)

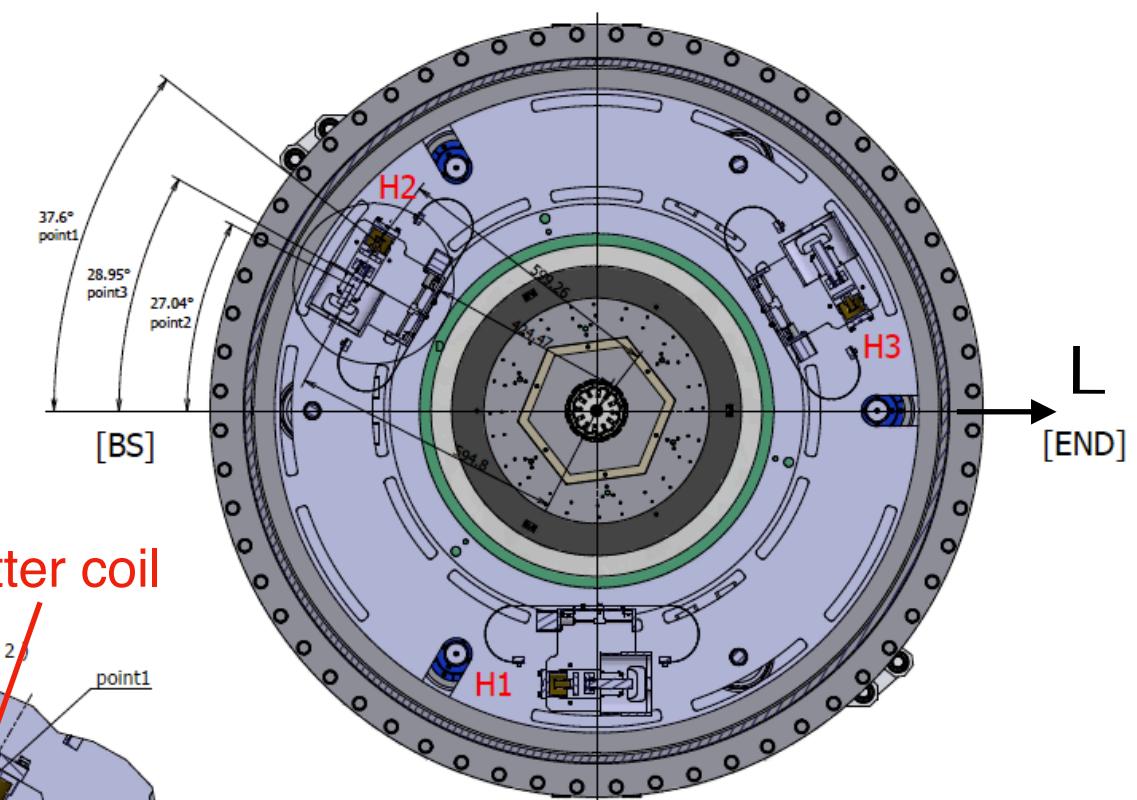


Four components on the top plate

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

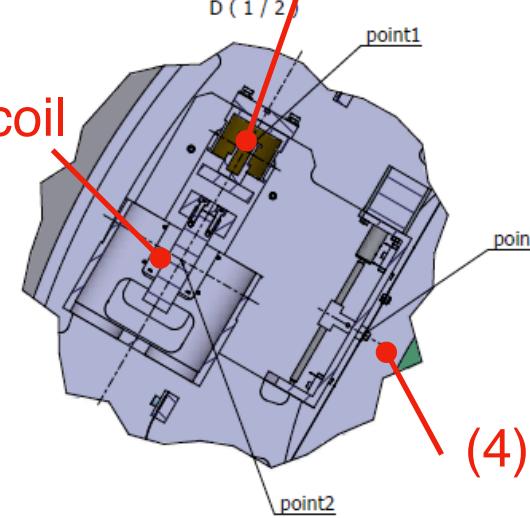


Above the top plate (B)



(1) LVDT emitter coil

(2) LVDT actuation coil



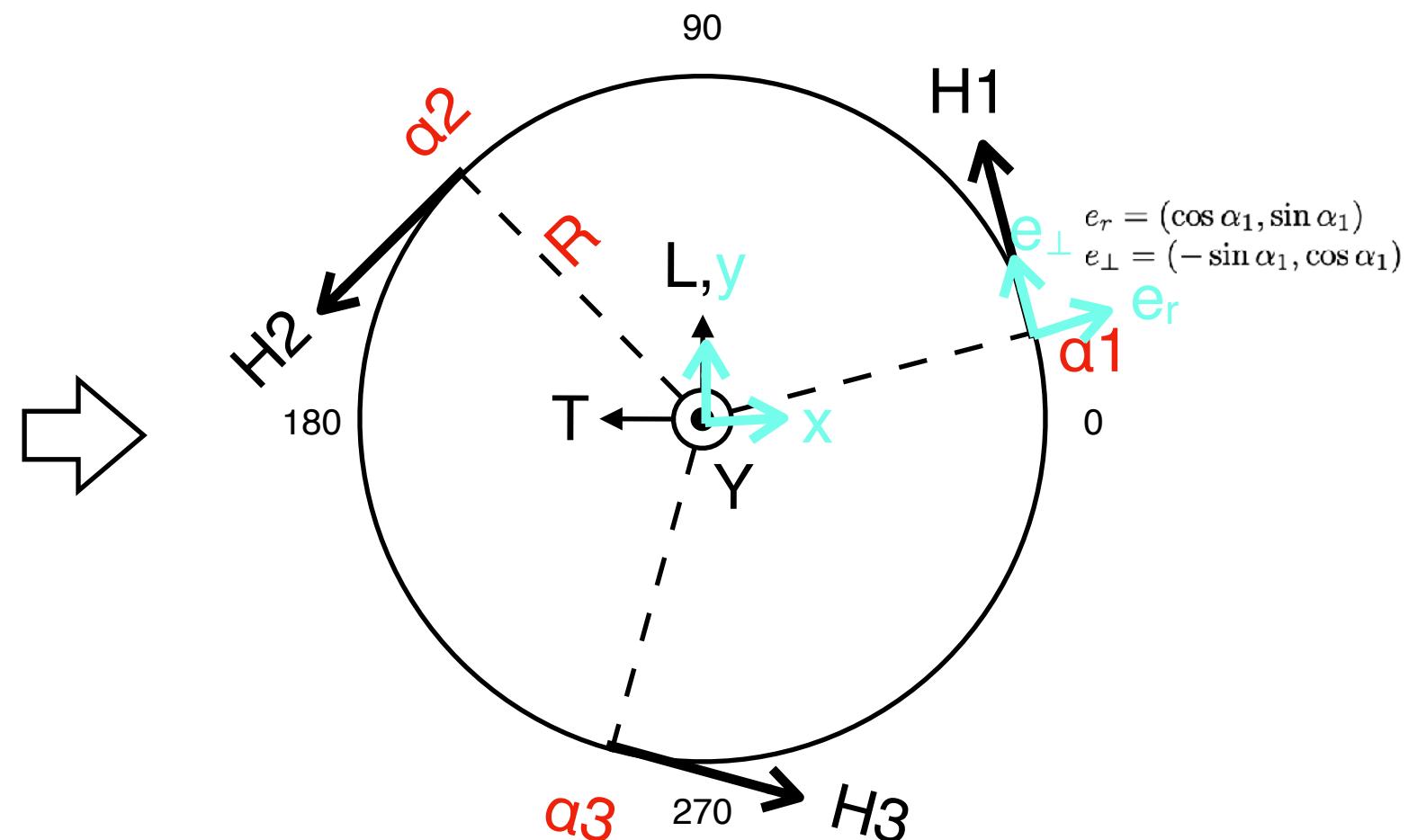
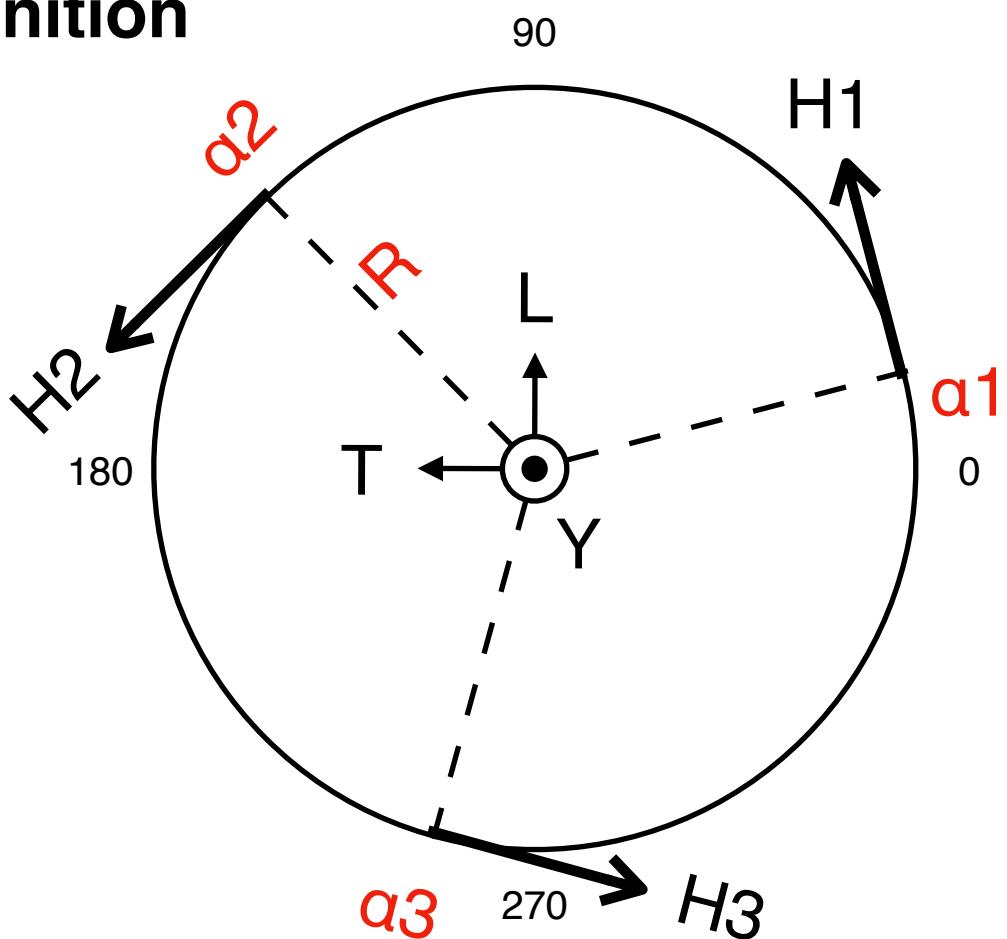
Bellow the top plate (C)

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

Top Plate / Diagonalization Matrix

JGW-E2012144-v10

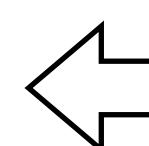
Definition



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](#)



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

$$\Updownarrow$$

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

$$\Updownarrow$$

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

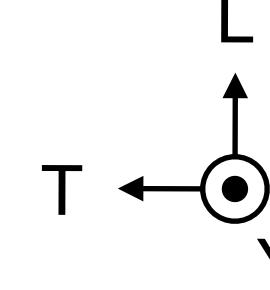
Top Plate / The location of ITMX

JGW-E2012144-v10

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

| | | |
|------------|-----------|-----------|
| LVDT | LVDT | FR |
| Emit. Coil | Act. Coil | Fix point |

[END]



$a_3 = a_2 - 120$

H3

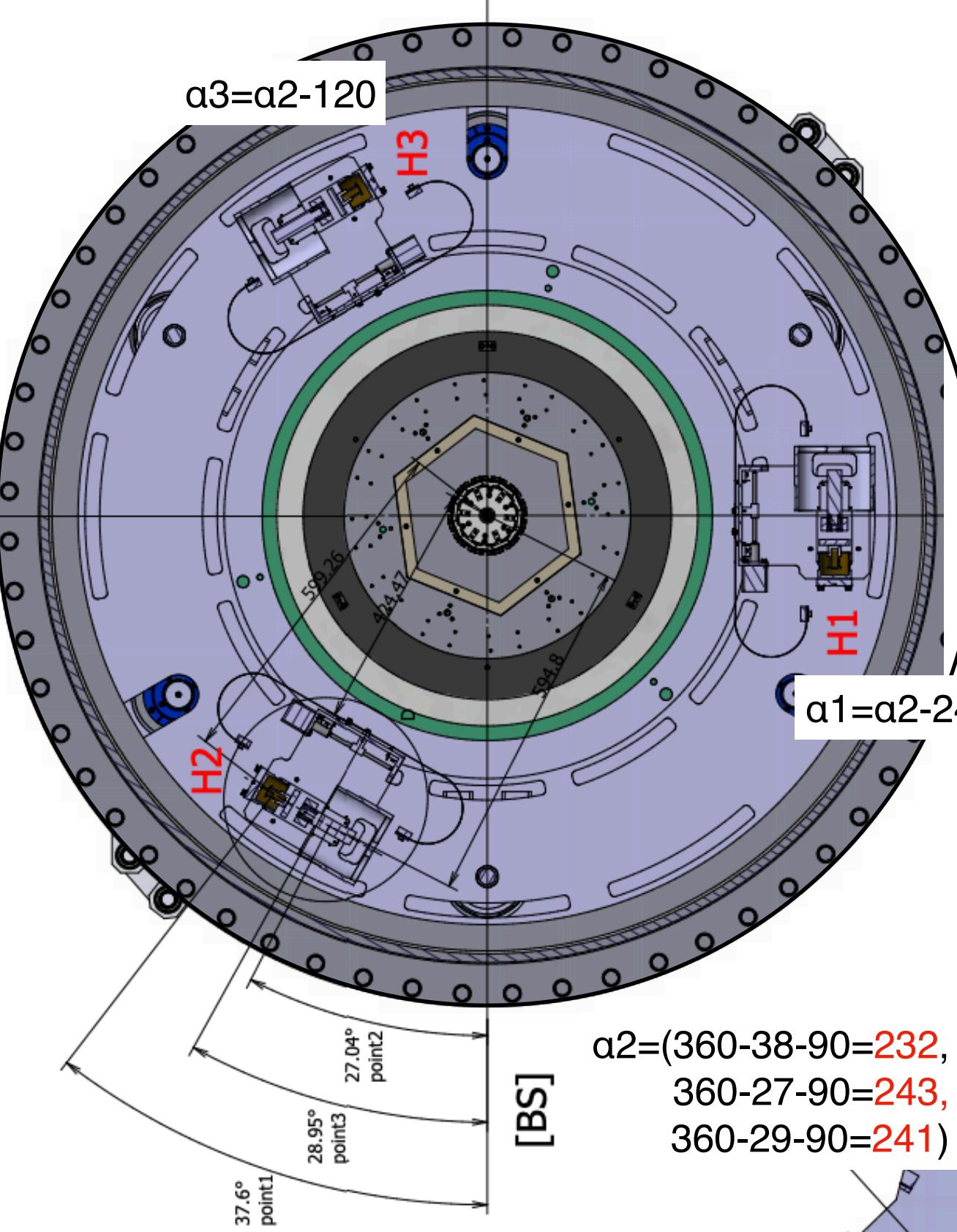
$a_1 = a_2 - 240$

H2

$a_1 = a_2 - 240$

C-C (1 : 5)

B-B (1 : 5)



$a_3 = 45 + 90 = 135$

$R = 0.478$

$a_1 = a_3 - 120$

$a_2 = a_3 + 120$

H2

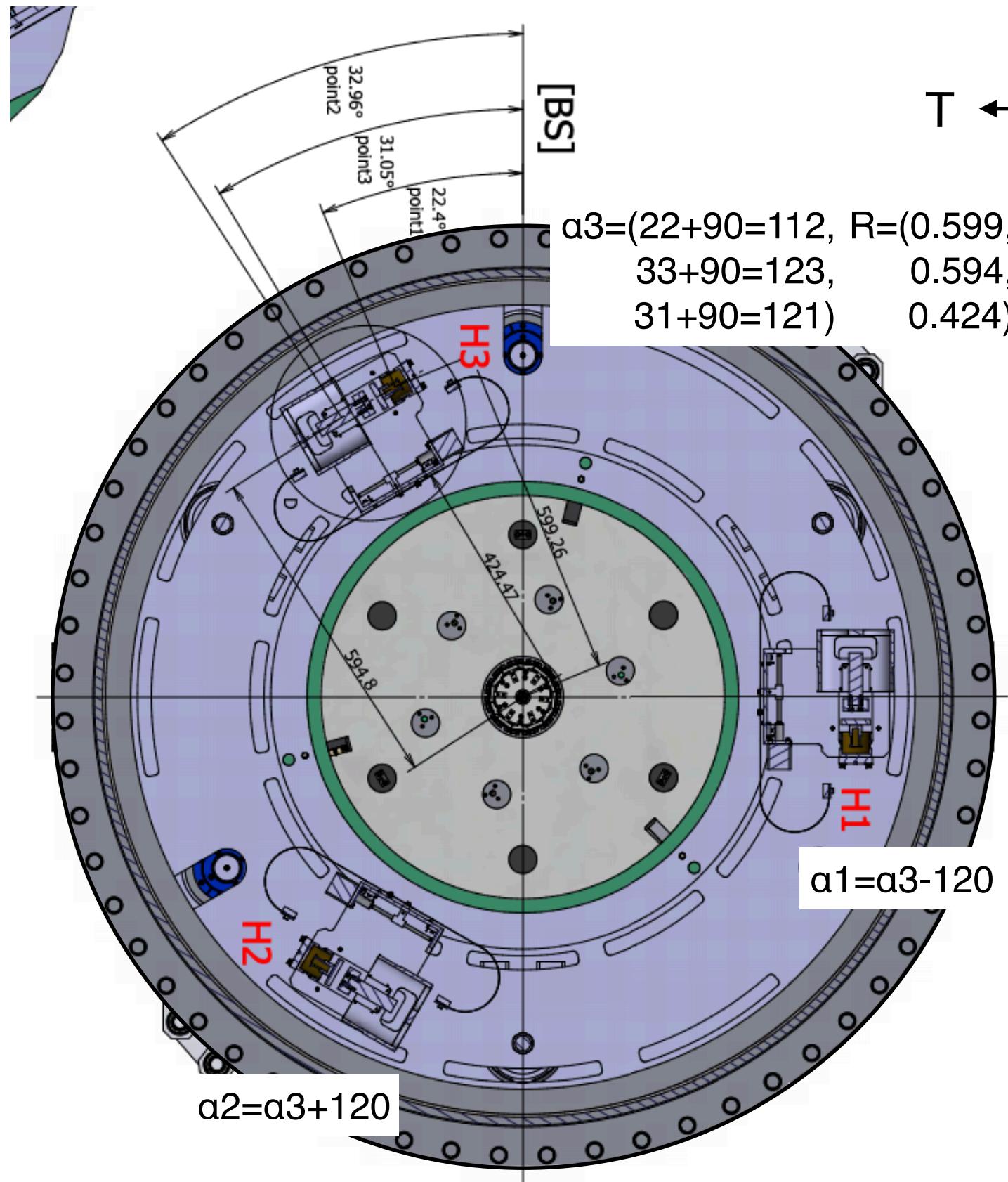
$a = \text{point1}$
Accelerometer

[END]

[BS]

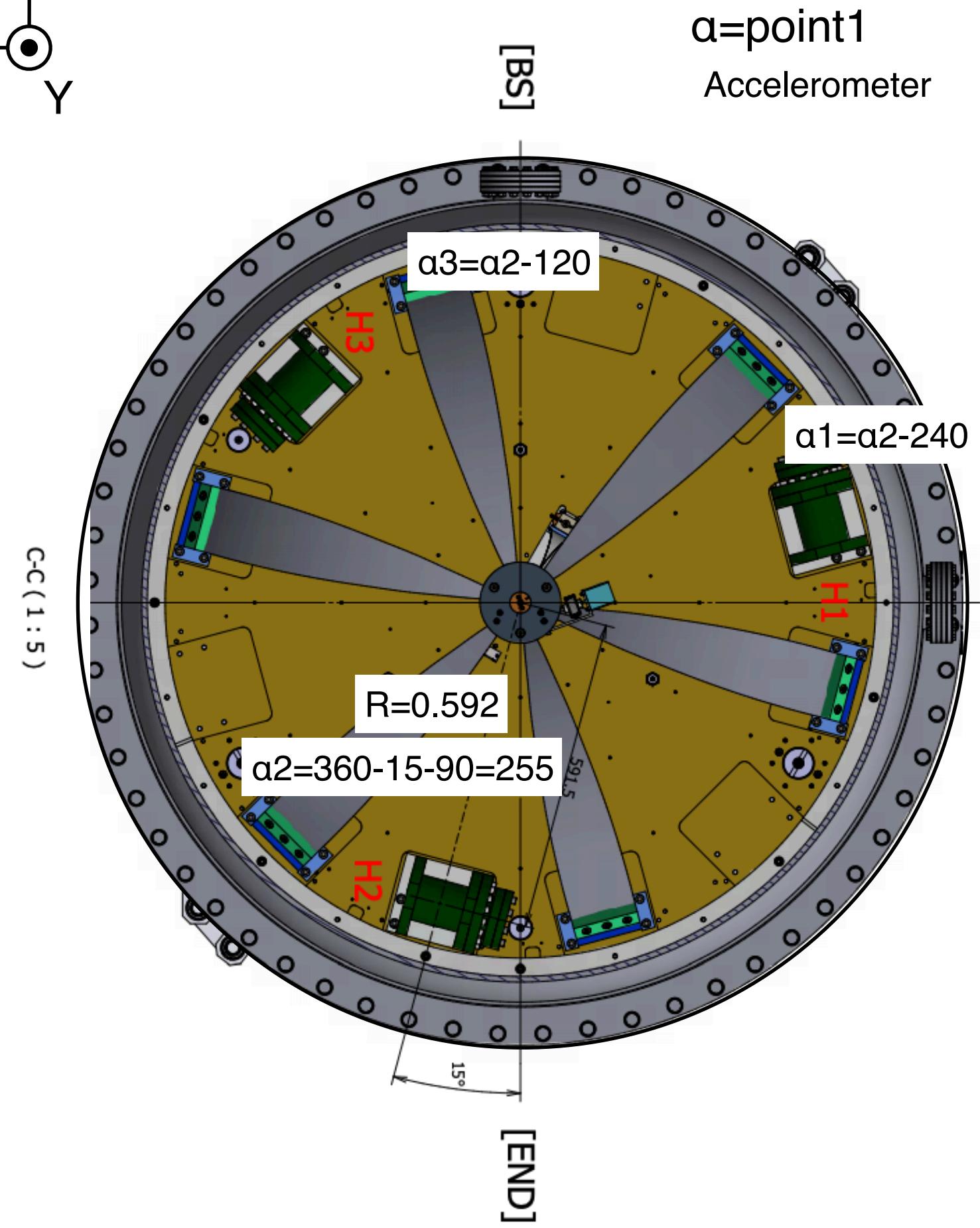
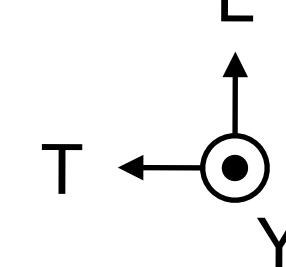
Top Plate / The location of ETMX

JGW-E2012144-v10



`a=(point1, point2, point3)`

LVDT LVDT FR
Emit. Coil Act. Coil Fix point



Top Plate / The location of ITMY

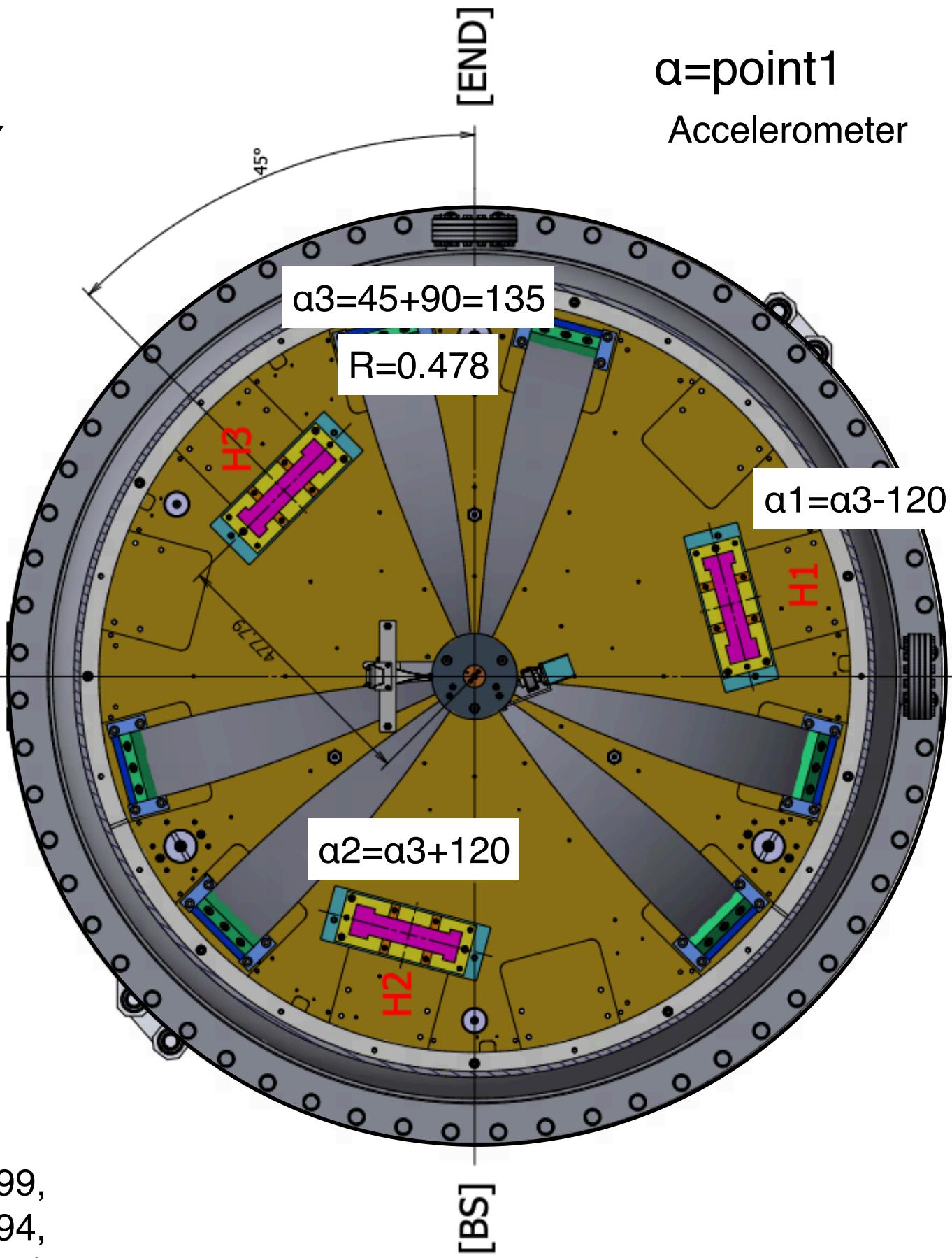
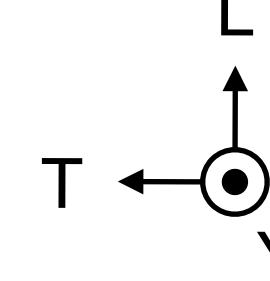
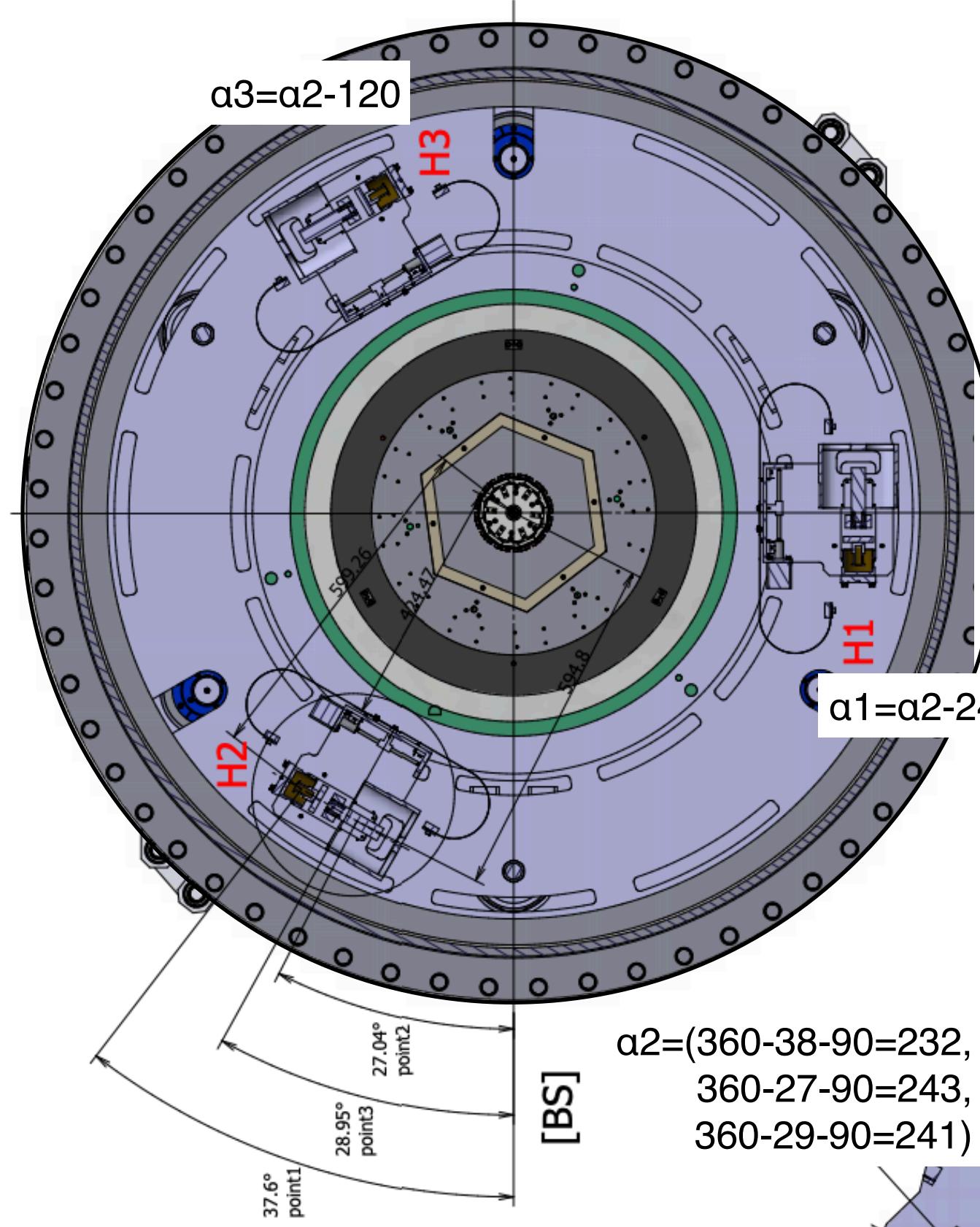
Same as the ITMX

JGW-E2012144-v10

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

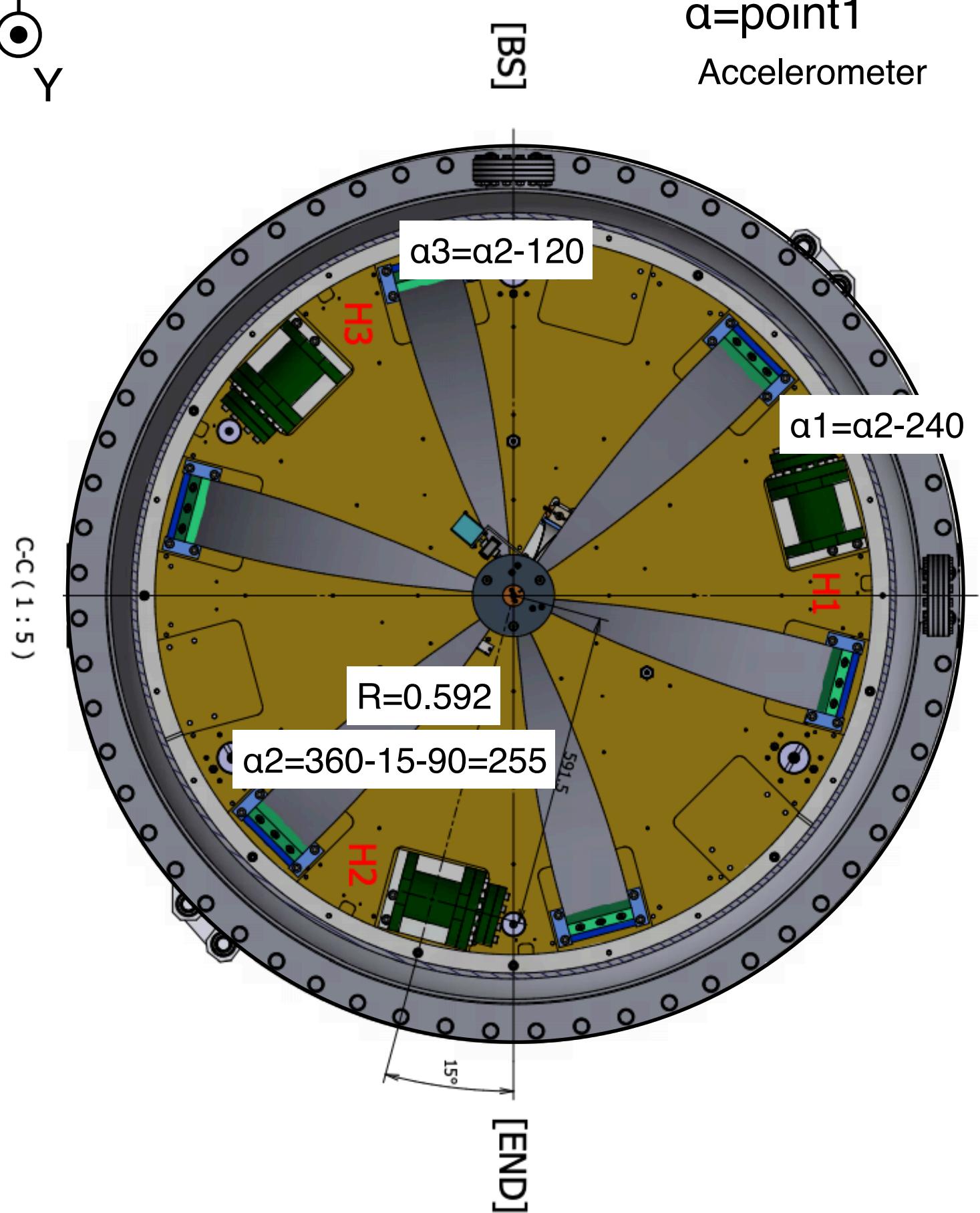
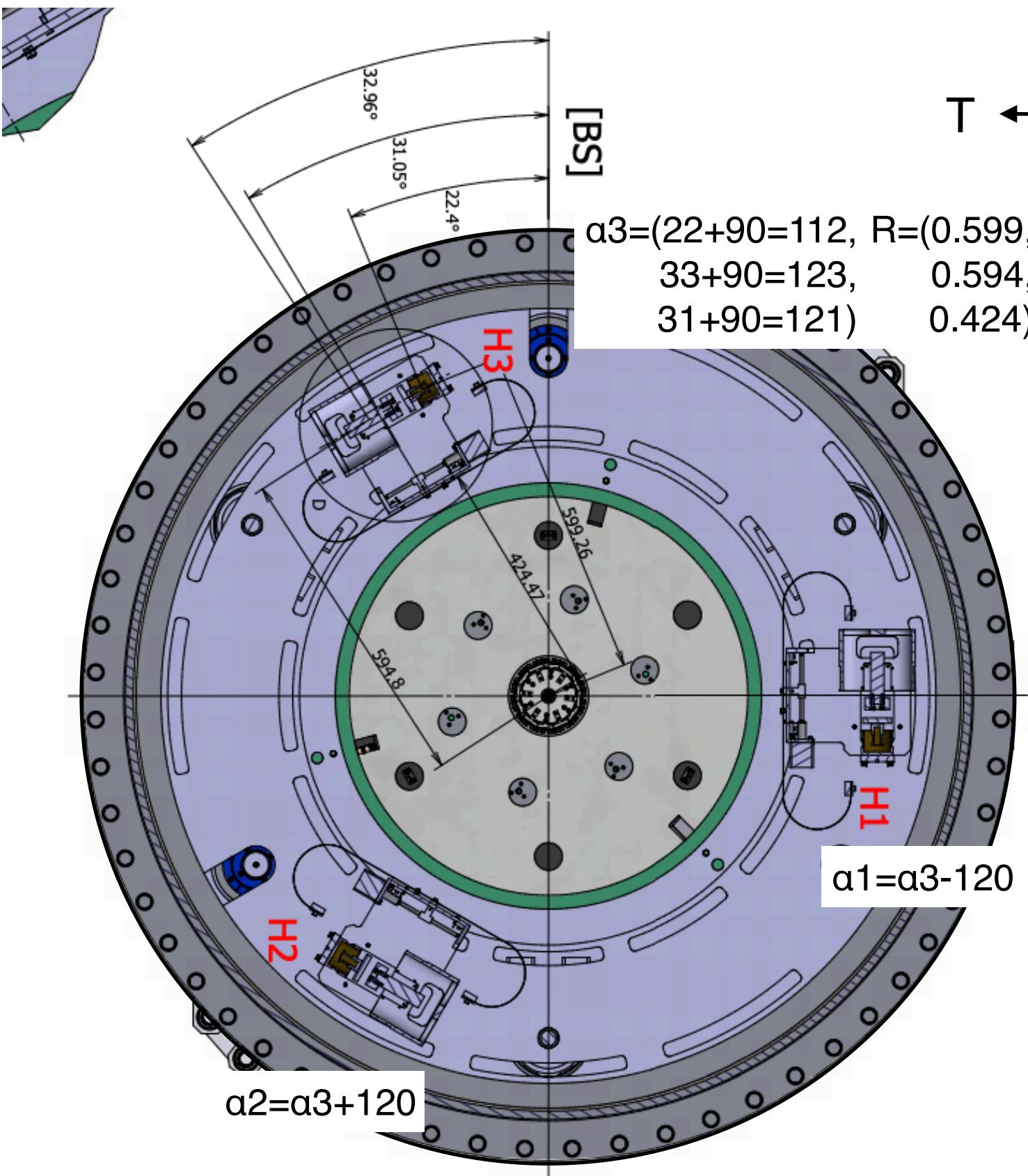
LVDT LVDT FR
Emit. Coil Act. Coil Fix point

[END]



Top Plate / The location of ETMY

Same as the ETMX W-E2012144-v10

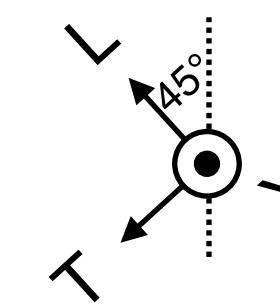
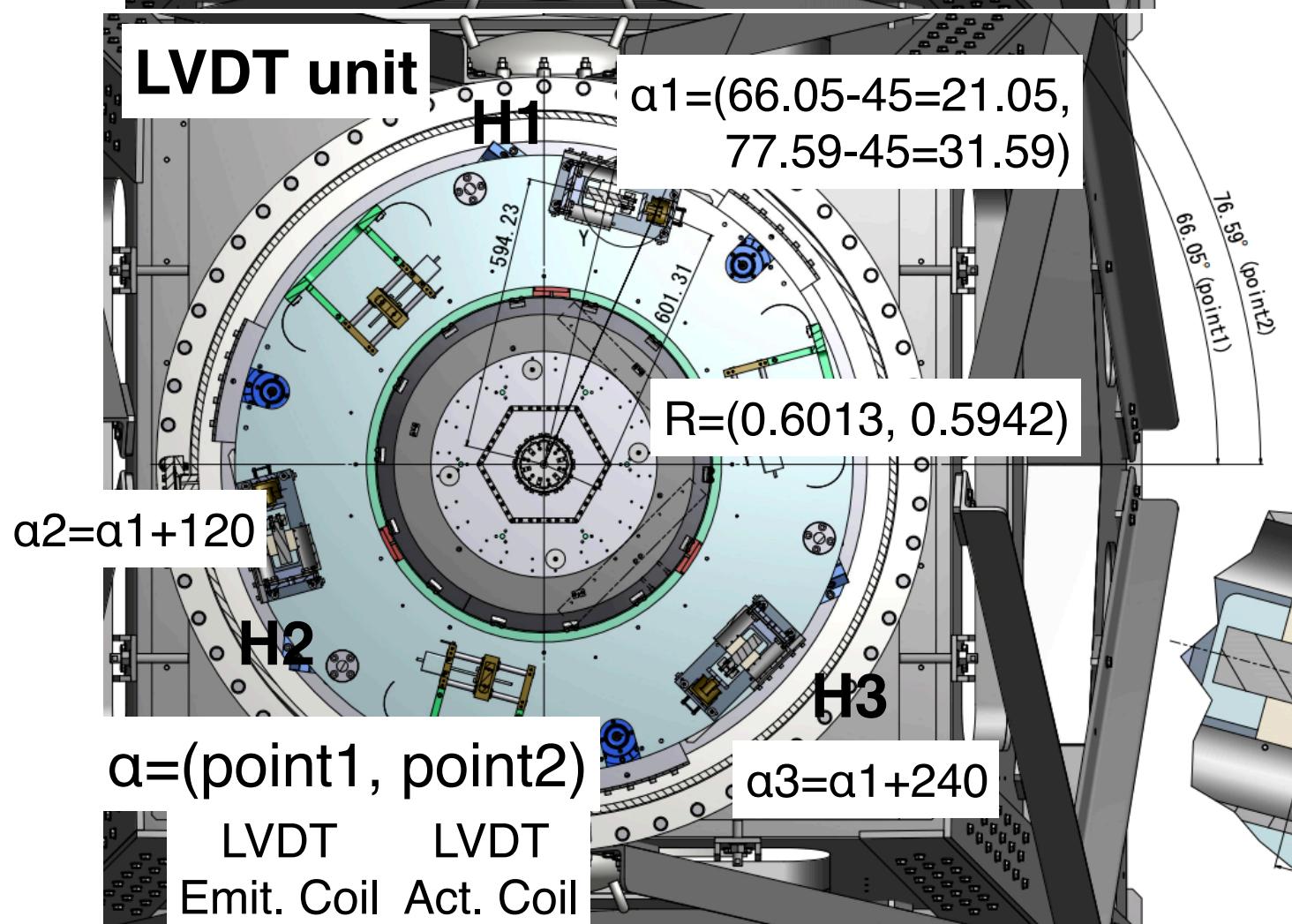
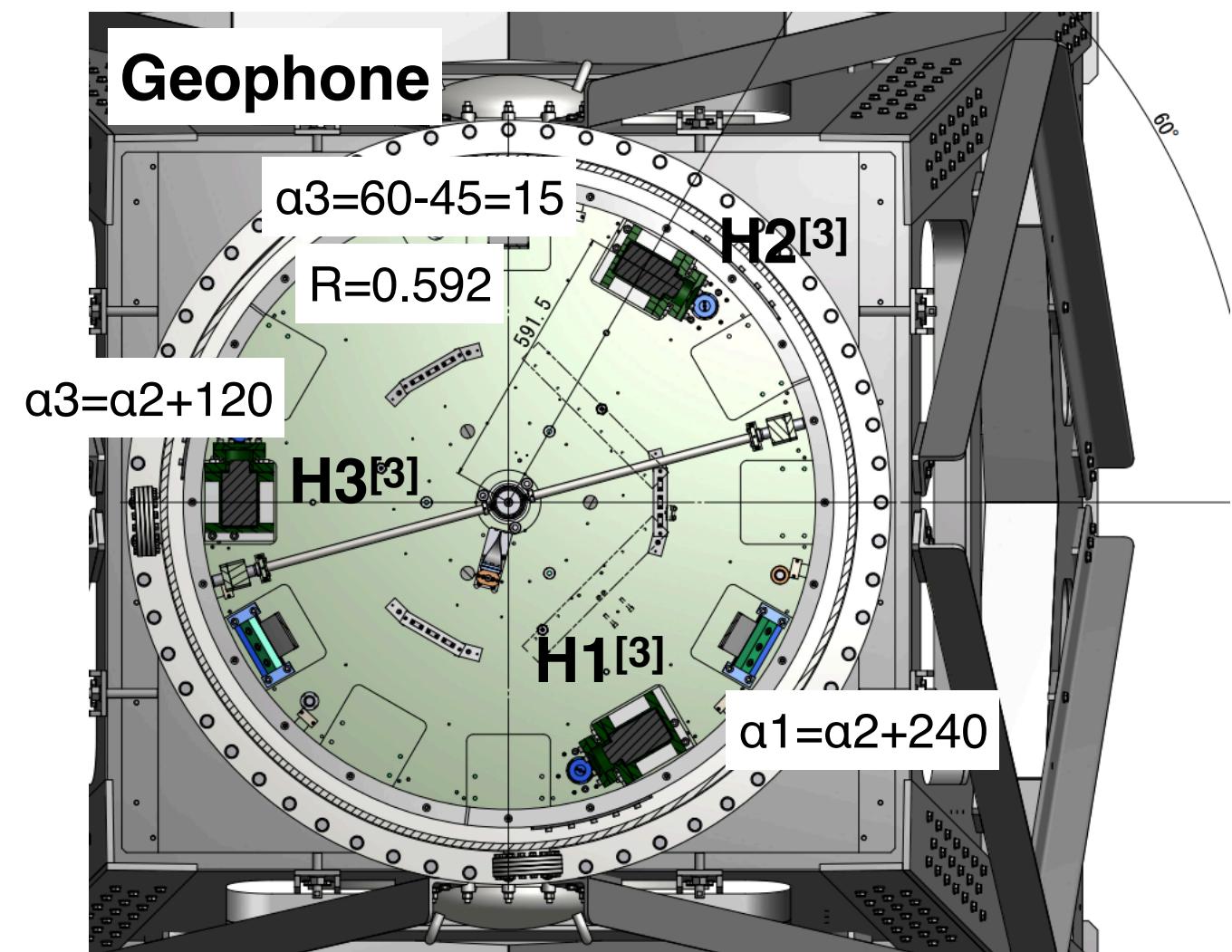
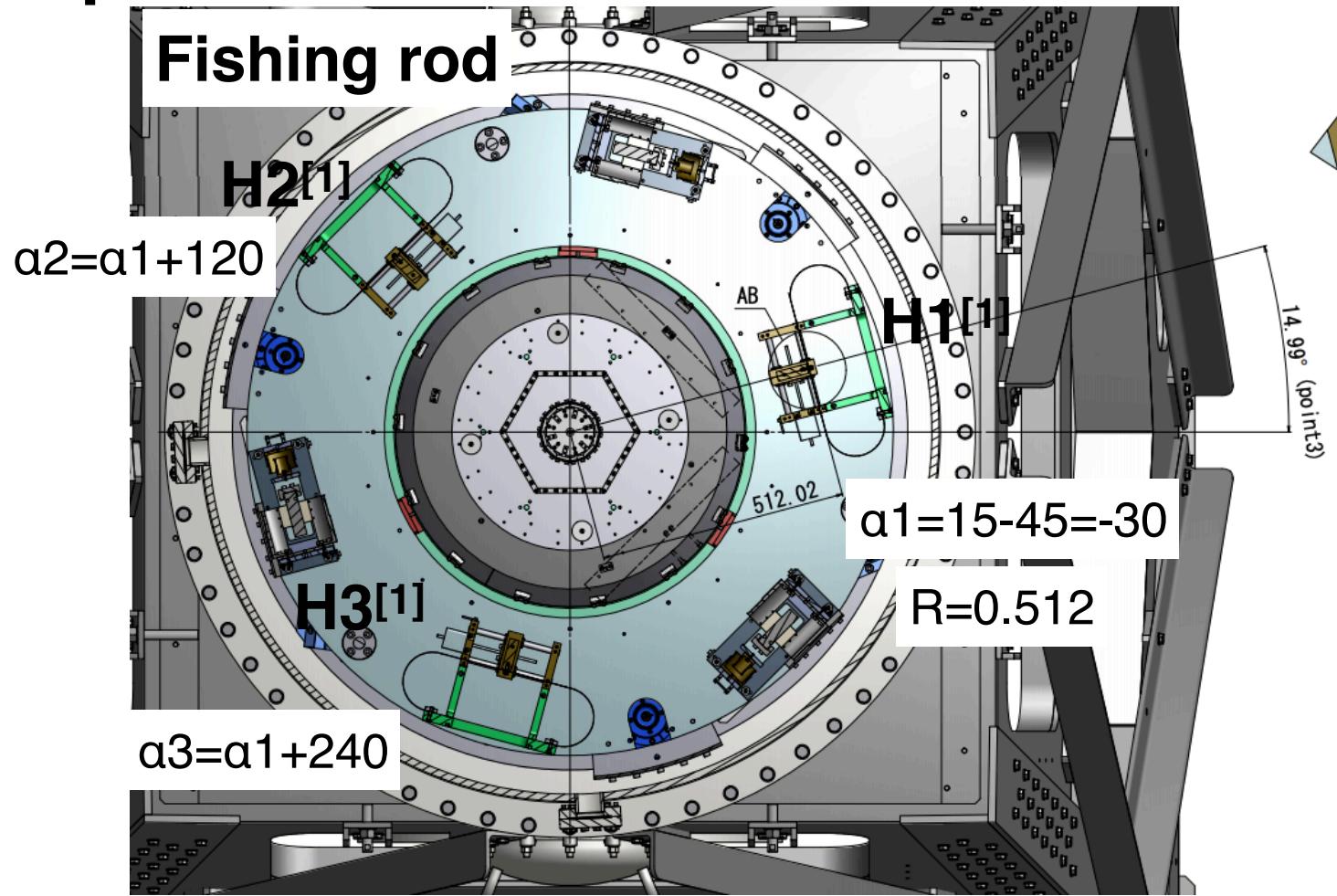


$a=(\text{point1}, \text{point2}, \text{point3})$

LVDT LVDT FR
Emit. Coil Act. Coil Fix point

Top Plate / The location of BS

JGW-E2012144-v10



[1] I'm not sure the label names for FRs.

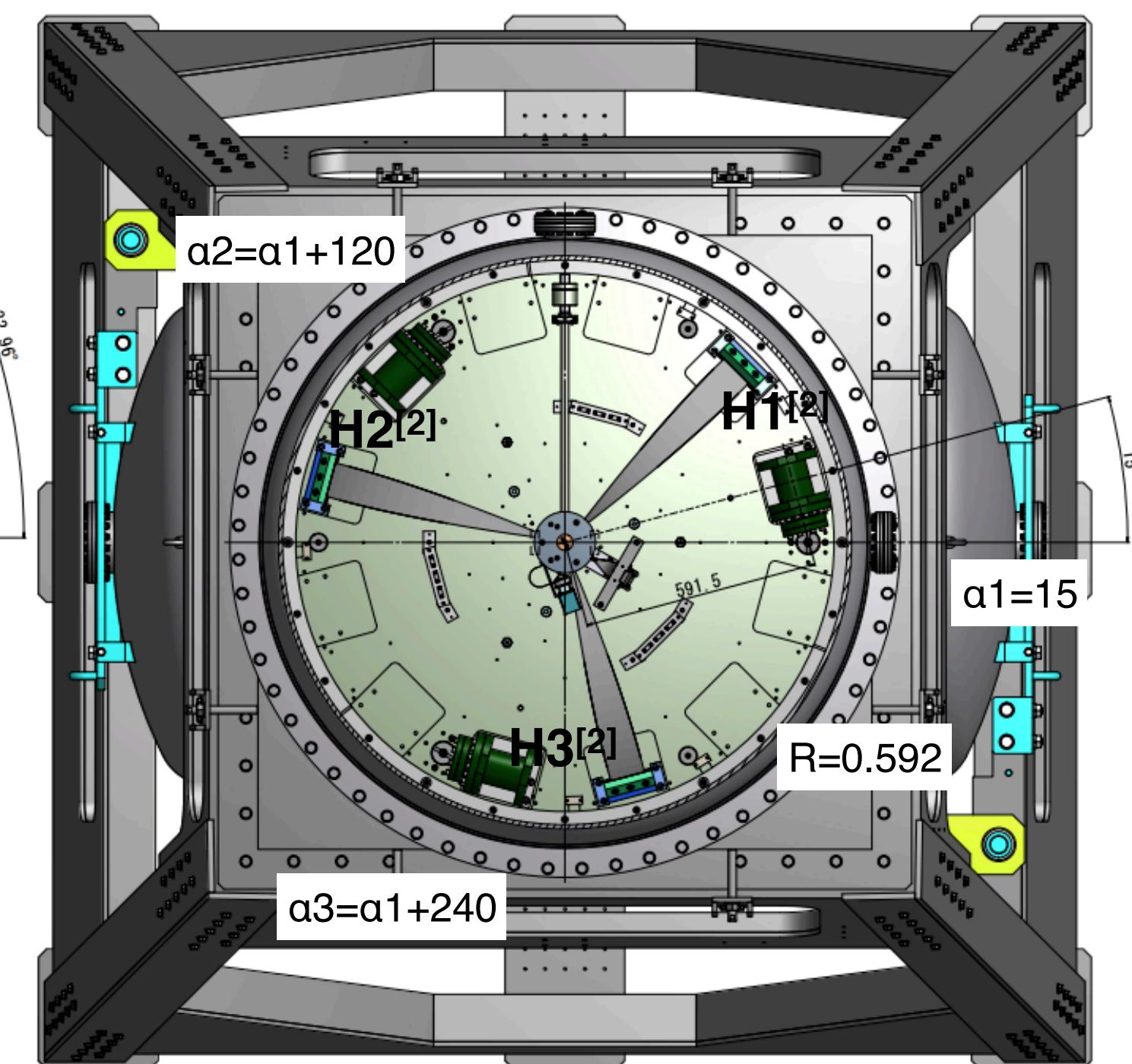
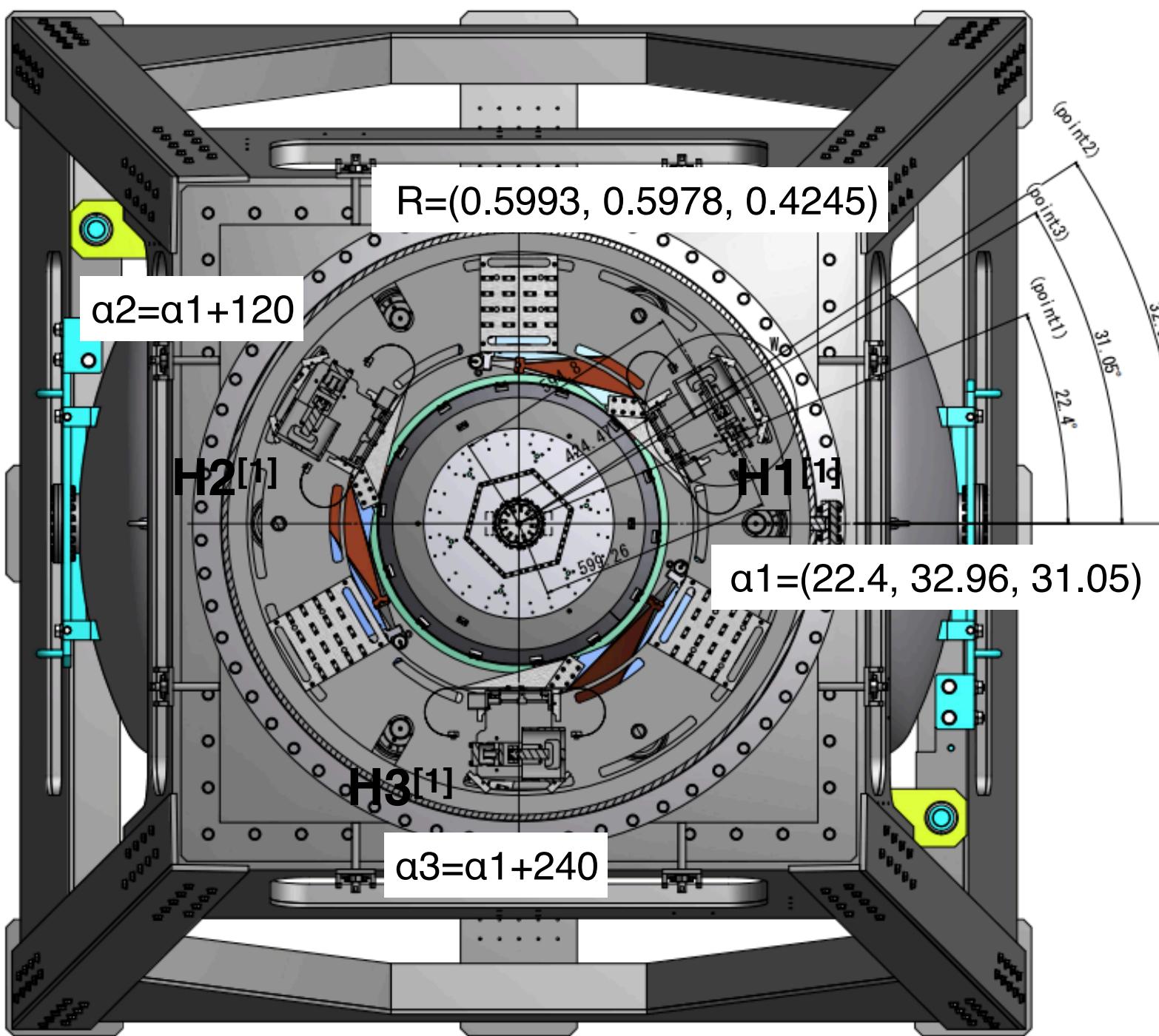
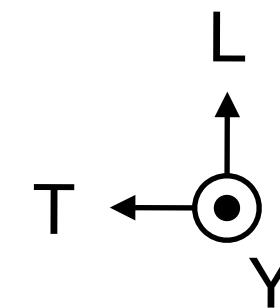
[3] I'm not sure the label names for geophone.

Top Plate / The location of SR

JGW-E2012144-v10

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

| | | |
|------------|-----------|-----------|
| 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-v10

(1) LVDT emitter coils

| | α_1 [deg] | α_2 [deg] | α_3 [deg] | R [m] | Reference | Check |
|------|---------------------|---------------------|---------------------|--------|--------------------------------------|-------|
| ETMX | -8 | 232 | 112 | 0.595 | JGW-D2012142-v1 (EX) | 三代 佐藤 |
| ITMX | -8 | 232 | 112 | 0.595 | JGW-D2012142-v1 (IX) | 三代 佐藤 |
| ETMY | -8 | 232 | 112 | 0.595 | JGW-D2012142-v1 (EY) | 三代 佐藤 |
| ITMY | -8 | 232 | 112 | 0.595 | JGW-D2012142-v1 (IY) | 三代 佐藤 |
| BS | 21.05 | 141.05 | 261.05 | 0.6013 | JGW-D1605092-v4 | 三代 雷 |
| SR2 | 22.4 | 142.4 | 262.4 | 0.5798 | JGW-D1707077-v7 | 三代 雷 |
| SR3 | 22.4 | 142.4 | 262.4 | 0.5798 | JGW-D1707077-v7 | 三代 雷 |
| SRM | 22.4 | 142.4 | 262.4 | 0.5798 | JGW-D1707077-v7 | 三代 雷 |

(2) LVDT actuator coils

| | α_1 [deg] | α_2 [deg] | α_3 [deg] | R [m] | Reference | Check |
|------|---------------------|---------------------|---------------------|--------|--------------------------------------|-------|
| ETMX | 3 | 243 | 123 | 0.599 | JGW-D2012142-v1 (EX) | 三代 佐藤 |
| ITMX | 3 | 243 | 123 | 0.599 | JGW-D2012142-v1 (IX) | 三代 佐藤 |
| ETMY | 3 | 243 | 123 | 0.599 | JGW-D2012142-v1 (EY) | 三代 佐藤 |
| ITMY | 3 | 243 | 123 | 0.599 | JGW-D2012142-v1 (IY) | 三代 佐藤 |
| BS | 31.59 | 151.59 | 271.59 | 0.5942 | JGW-D1605092-v4 | 三代 雷 |
| SR2 | 32.95 | 152.95 | 272.95 | 0.5993 | JGW-D1707077-v7 | 三代 雷 |
| SR3 | 32.95 | 152.95 | 272.95 | 0.5993 | JGW-D1707077-v7 | 三代 雷 |
| SRM | 32.95 | 152.95 | 272.95 | 0.5993 | JGW-D1707077-v7 | 三代 雷 |

(3) Accelerometer

| | α_1 [deg] | α_2 [deg] | α_3 [deg] | R [m] | Reference | Check |
|------|---------------------|---------------------|---------------------|-------|--|-------|
| ETMX | 15 | 255 | 135 | 0.592 | JGW-D2012142-v1 (EX) [1] | 三代 佐藤 |
| ITMX | 15 | 255 | 135 | 0.478 | JGW-D2012142-v1 (IX) | 三代 佐藤 |
| ETMY | 15 | 255 | 135 | 0.592 | JGW-D2012142-v1 (EY) [1] | 三代 佐藤 |
| ITMY | 15 | 255 | 135 | 0.478 | JGW-D2012142-v1 (IY) | 三代 佐藤 |
| BS | 15 | 135 | 255 | 0.592 | JGW-D1605092-v4 | 三代 雷 |
| SR2 | 15 | 135 | 255 | 0.592 | JGW-D1707077-v7 | 三代 雷 |
| SR3 | 15 | 135 | 255 | 0.592 | JGW-D1707077-v7 | 三代 雷 |
| SRM | 15 | 135 | 255 | 0.592 | JGW-D1707077-v7 | 三代 雷 |

(4) Fixing point of the FR

| | α_1 [deg] | α_2 [deg] | α_3 [deg] | R [m] | Reference | Check |
|------|---------------------|---------------------|---------------------|--------|--------------------------------------|-------|
| ETMX | 1 | 241 | 121 | 0.424 | JGW-D2012142-v1 (EX) | 三代 佐藤 |
| ITMX | 1 | 241 | 121 | 0.424 | JGW-D2012142-v1 (IX) | 三代 佐藤 |
| ETMY | 1 | 241 | 121 | 0.424 | JGW-D2012142-v1 (EY) | 三代 佐藤 |
| ITMY | 1 | 241 | 121 | 0.424 | JGW-D2012142-v1 (IY) | 三代 佐藤 |
| BS | -30 | 90 | 210 | 0.512 | JGW-D1605092-v4 | 三代 雷 |
| SR2 | 31.05 | 151.05 | 271.05 | 0.4245 | JGW-D1707077-v7 | 三代 雷 |
| SR3 | 31.05 | 151.05 | 271.05 | 0.4245 | JGW-D1707077-v7 | 三代 雷 |
| SRM | 31.05 | 151.05 | 271.05 | 0.4245 | JGW-D1707077-v7 | 三代 雷 |

[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-v10

Geometric Anti-Spring

JGW-E2012144-v10

Bottom Filter

JGW-E2012144-v10

Marionetta Mass

JGW-E2012144-v10

Optical Lever

JGW-E2012144-v10

Manual

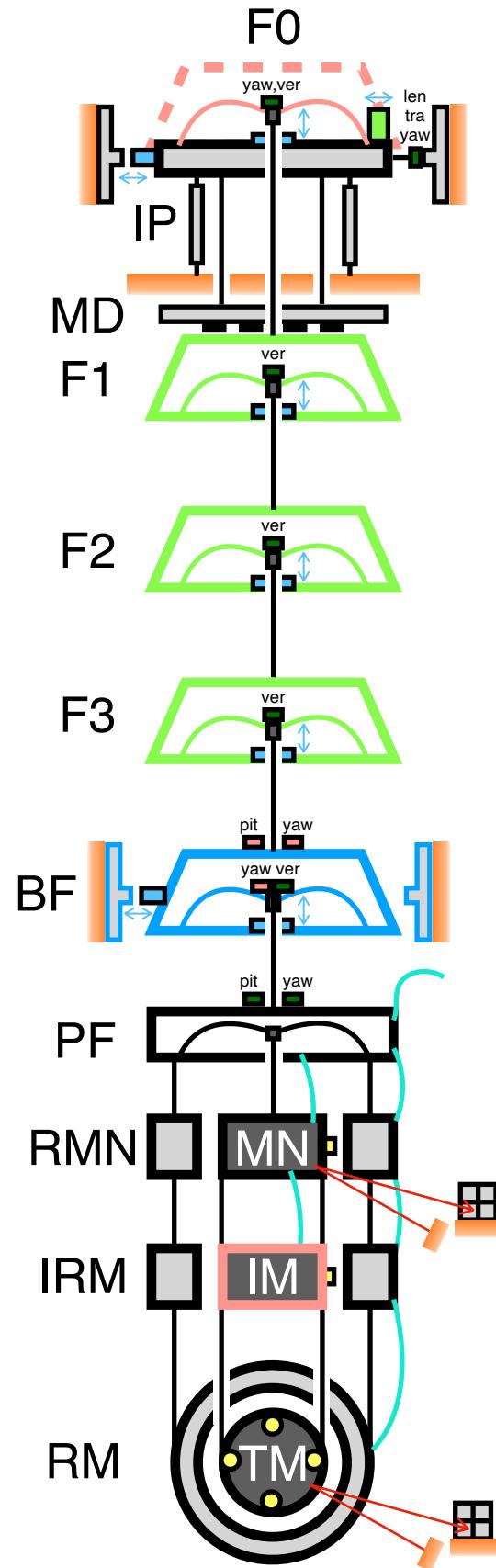
- Installation manual of OpLev : [JGW-T1707228-v6](#)
- Length Sensing : [JGW-T1605788-v11](#)
- OpLev setup for SR3 : [JGW-G1808874-v1](#)

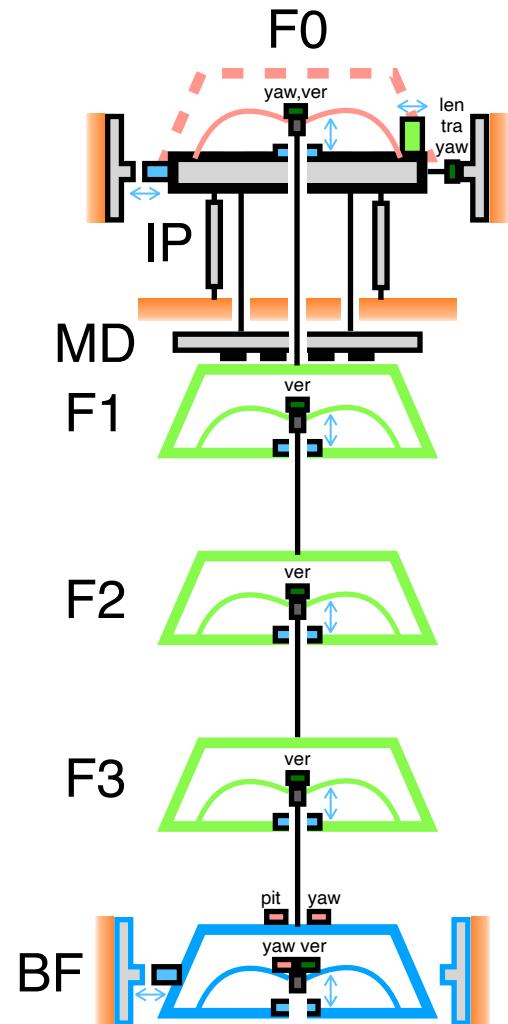
Sketch of the OpLev table

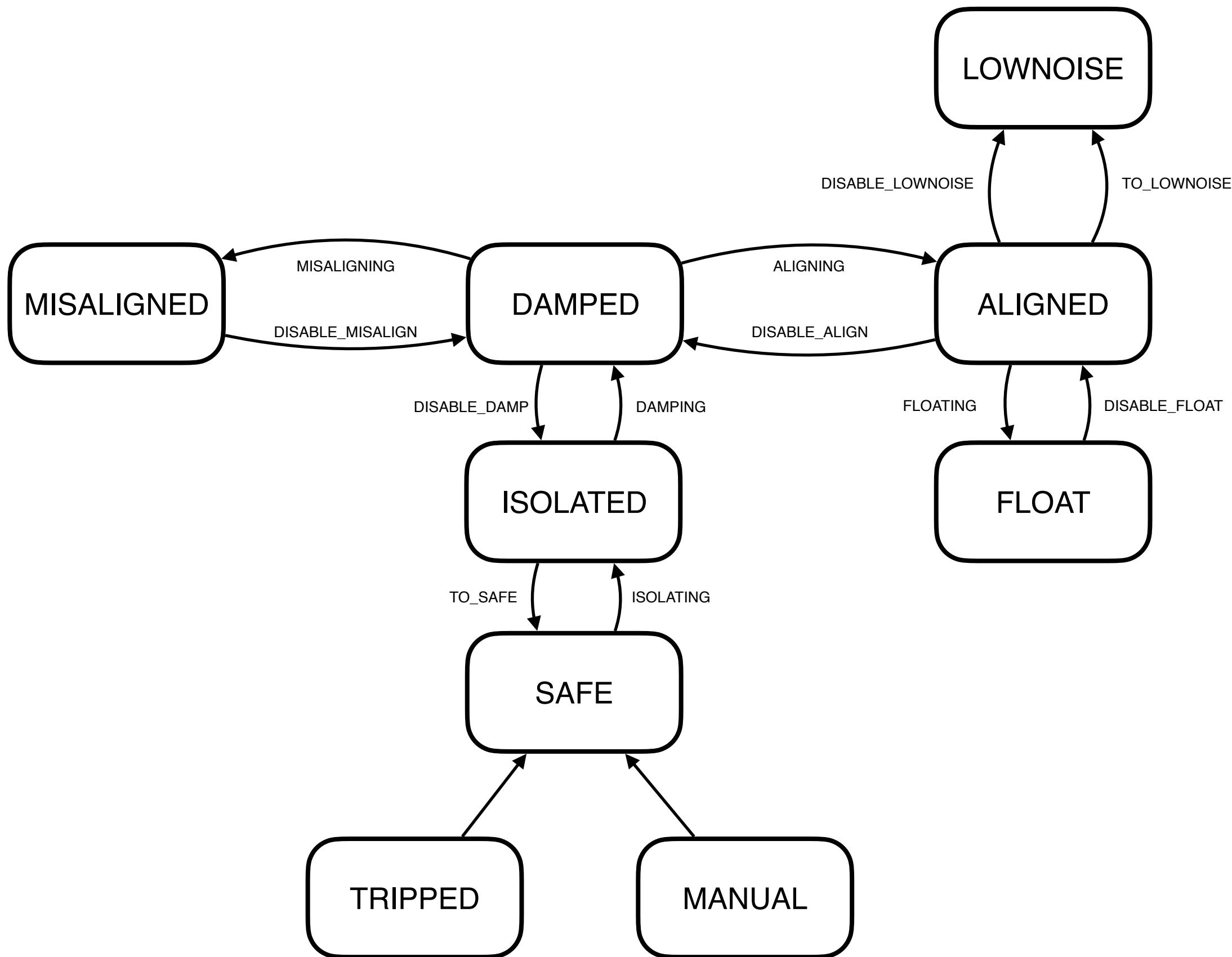
- PRM : [JGW-D1909596-v2](#)
- PR2 : [JGW-D1605877-v2](#)
- PR3 : [JGW-D1605867-v4](#)
- BS : [JGW-D1909928-v1 \(Old?\)](#)
- SRs : [JGW-D1809594-v3](#)
- TMs : [JGW-D1707064-v2](#)
- MNs : ???

Procedure

JGW-E2012144-v10







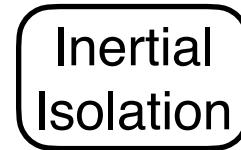
Real Time Model

JGW-E2012144-v10

Strategy for the Vibration Isolation

JGW-E2012144-v10

Inertial
Isolation



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

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

