Status of the Signal Recycling Mirrors Suspensions of KAGRA

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On behalf of Type B team.

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(6) Decay time measurements.

(7) SR Preisolator.

(8) IP Sensor / Actuator diagonalization.

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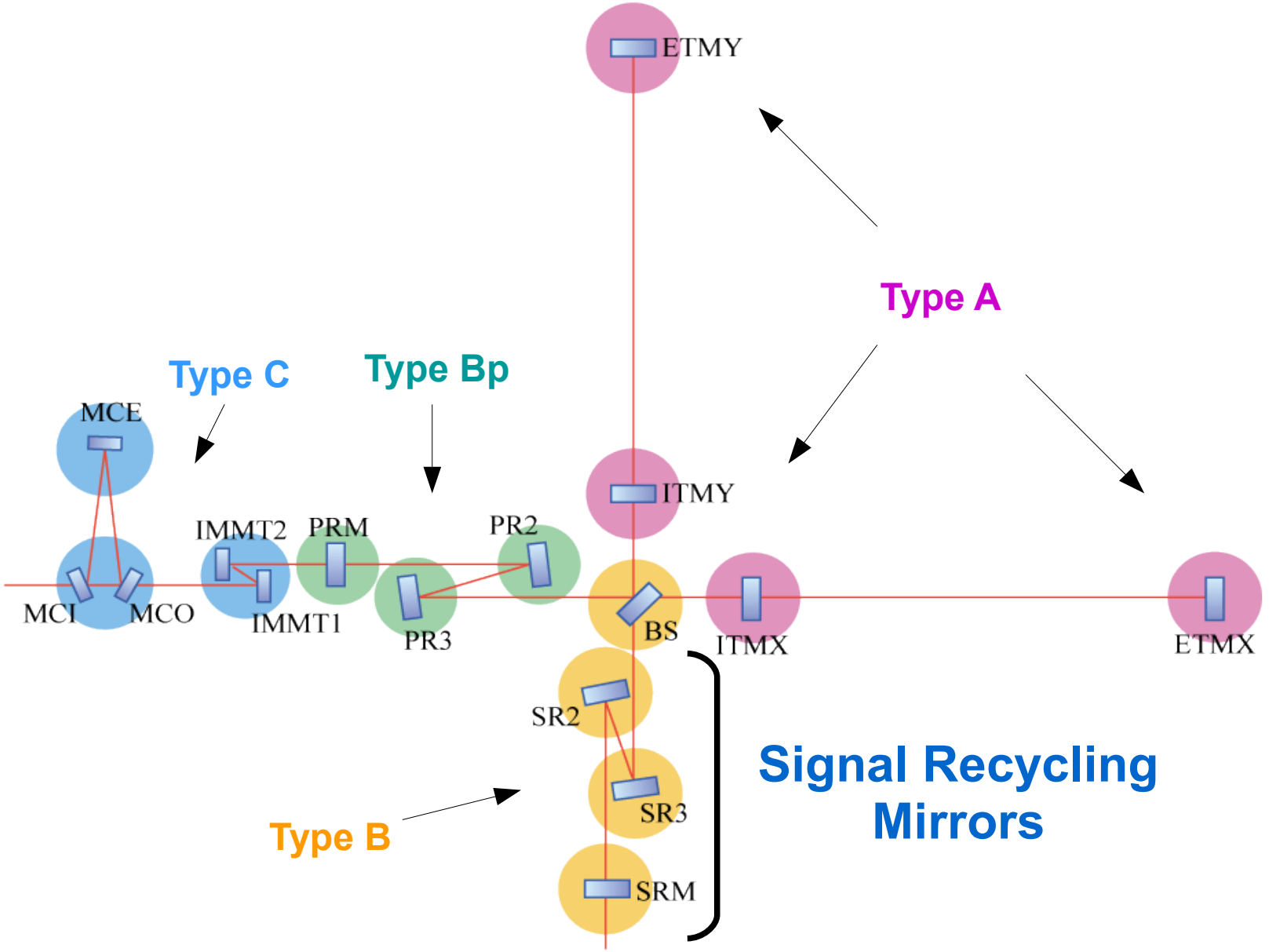
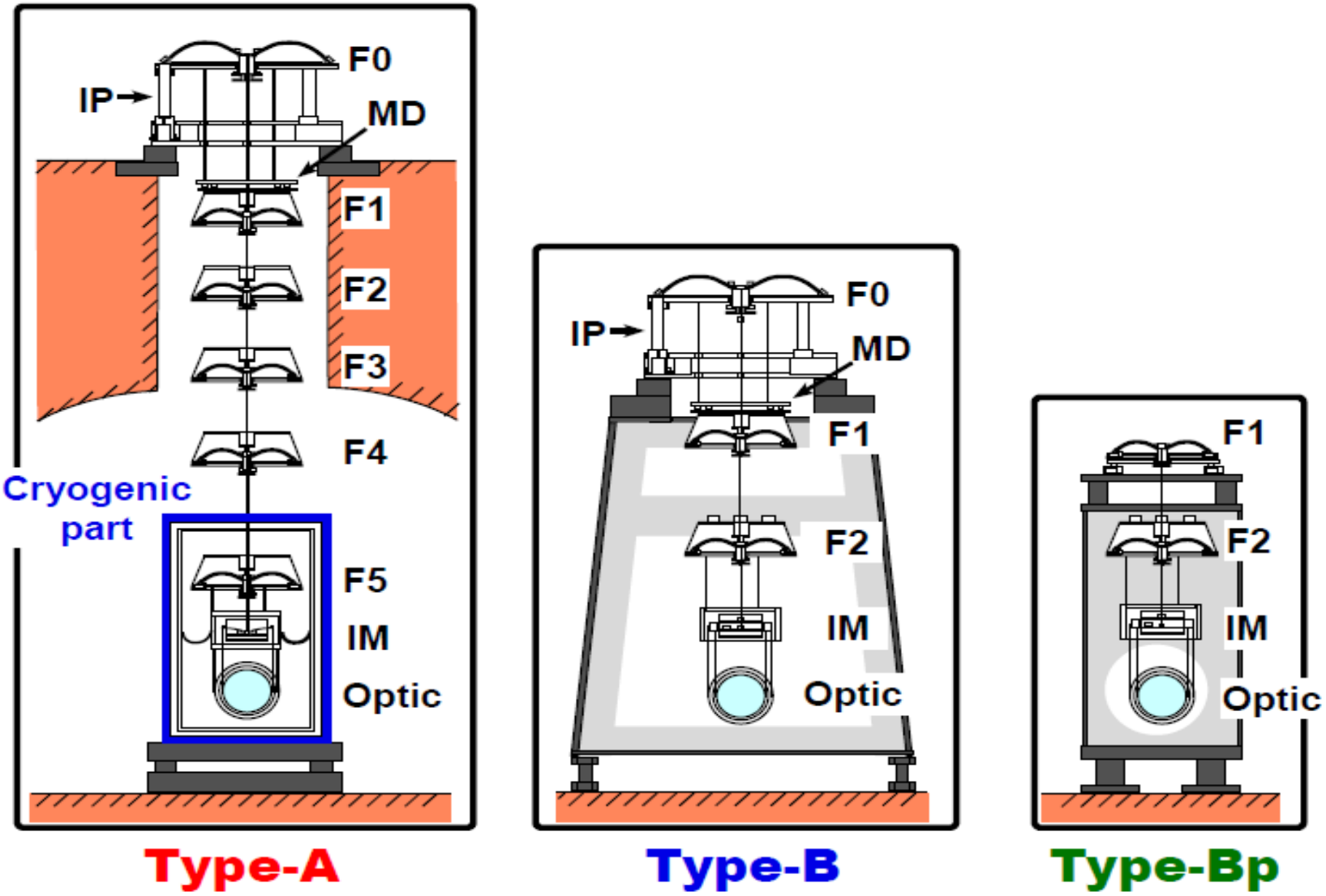
Introduction: VIS Suspensions



Introduction:VIS Suspensions



SR Stages

- SR2.
- SR3.
- SRM.

Pre-Isolator

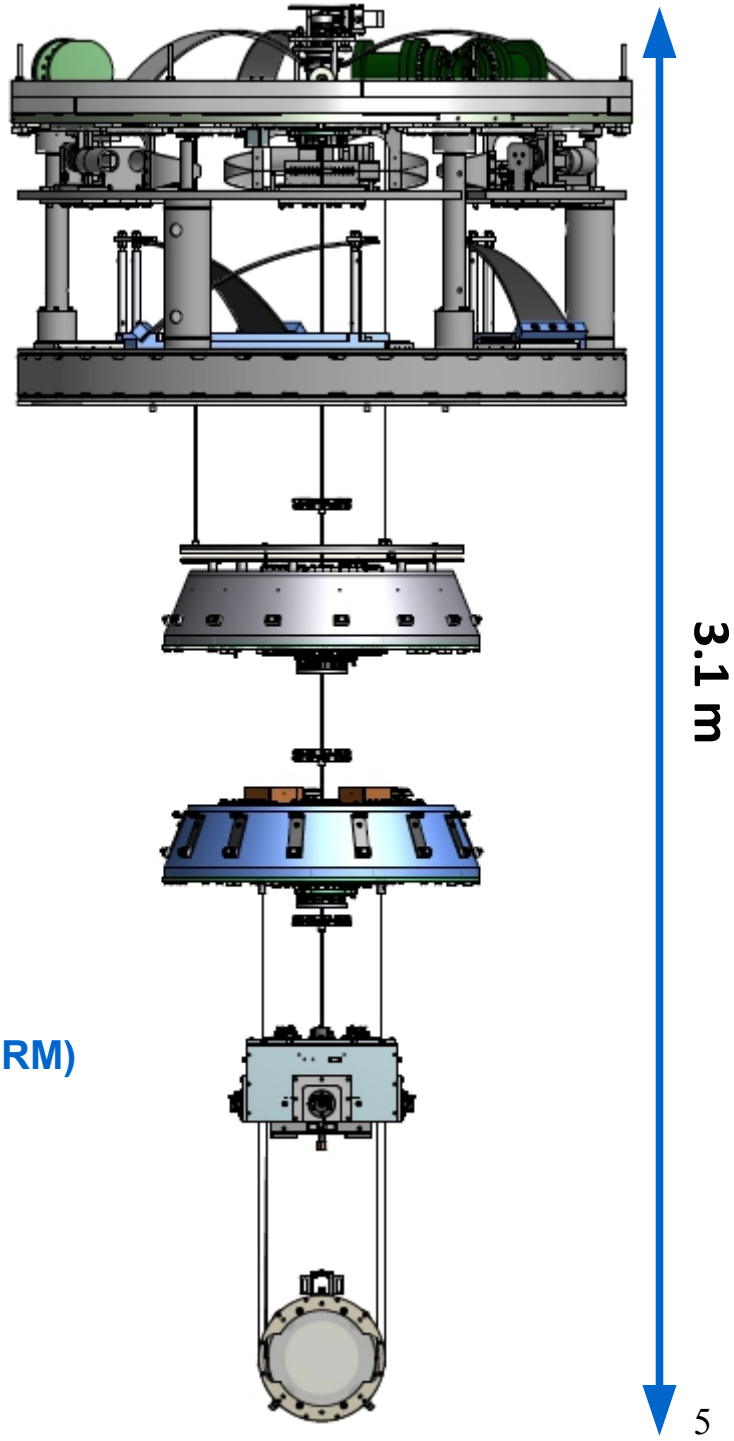
- Top Filter (TF)
- Filter0 (F0)
- Inverted Pendulum (IP)

GAS Filter chain

- Magnetic Damper (MD)
- Standard Filter (SF)
- Bottom Filter (BF)

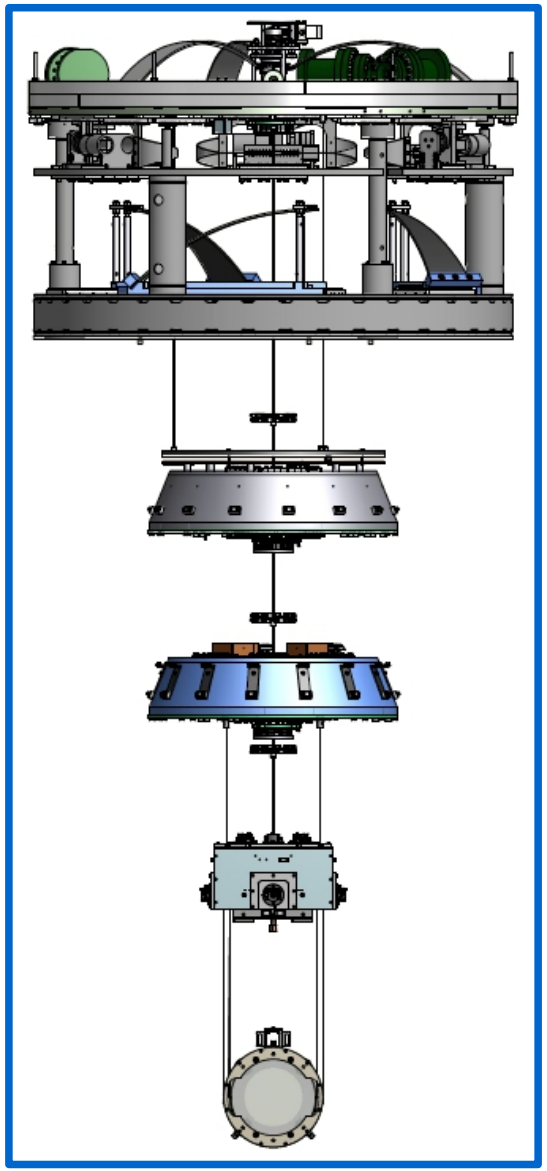
Payload

- Intermediate Recoil Mass (IRM)
- Intermediate Mass (IM)
- Recoil Mass (RM)
- Optics (SR)



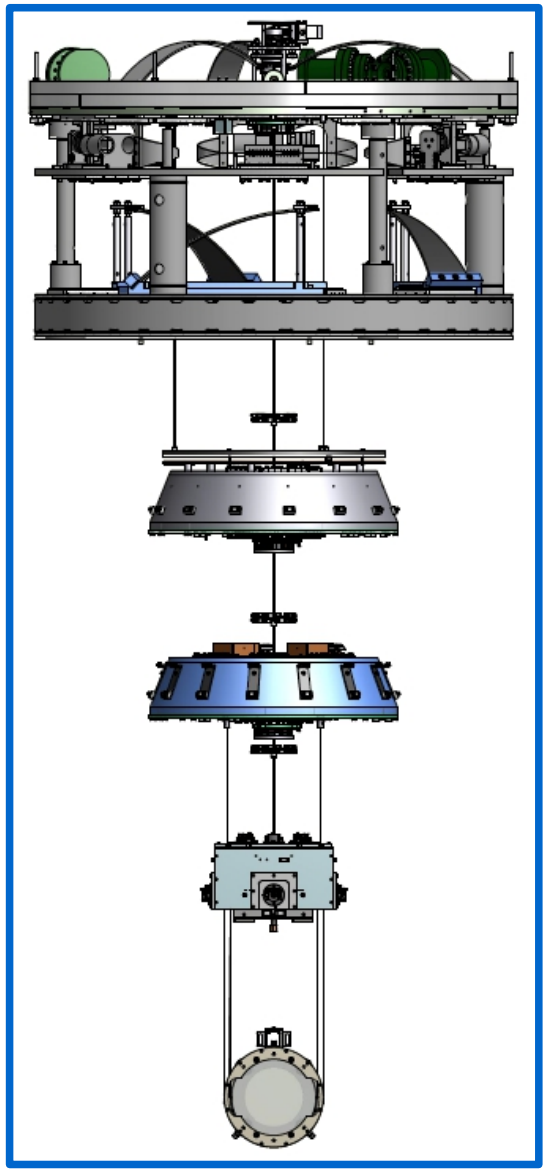
Status of assembly

SR3



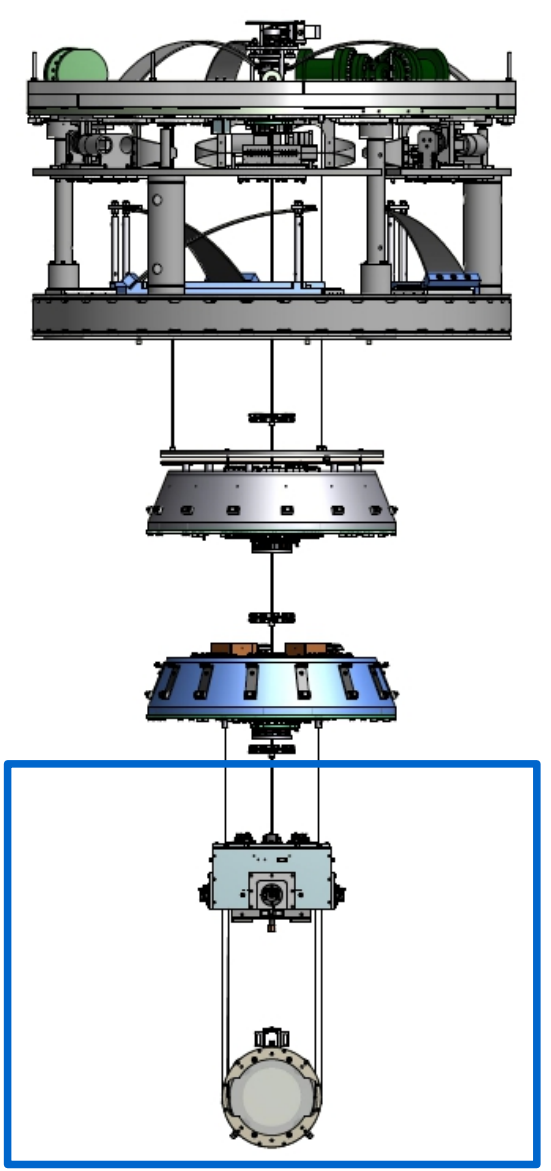
Installed.

SR2

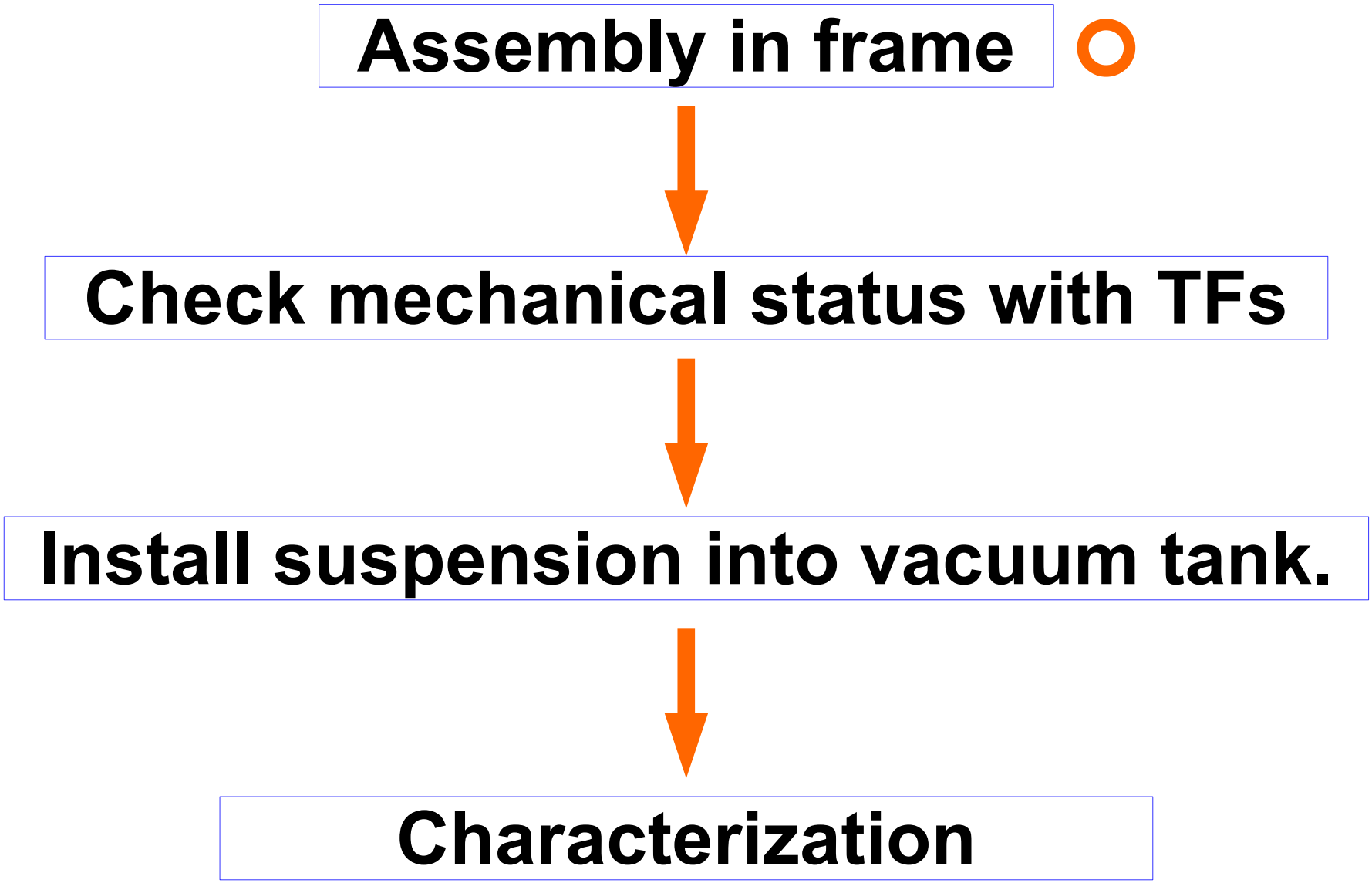


Assembled.

SRM



Assembled.


Assembly in frame
Check mechanical status with TFs
Install suspension into vacuum tank.
Characterization

Simulated and measured TFs

SUMCON in Mathematica
spension odel structor

SUMCON Version:1.4

About SUMCON | Version Info | Refresh

New Model | Load Model | Save Model | TypeB_SR3_GAS_freq_IP_new_stiff_updated_20180909.m

Model Construction | Calculation Result | Export Model

Step 1. Define Rigid Bodies

1–1 Set Body Names
1–2 Set Mass & MoI
1–3 Set Body Shapes
1–4 Set Initial Position

Body:

GND	Name	M [kg]	Ixx [kgm2]	Iyy [kgm2]	Izz [k
O	g	0	0	0	0
	F0	554.	97.5	191.4	97.5
	MD	16.97	0.7038	1.4061	0.702
	F1	91.31	3.8399	6.4676	3.839
	F2	100.21	3.66244	6.09594	3.670
	IR	8.933	0.1762	0.29221	0.182
	IM	26.177	0.15267	0.2491	0.183
	RM	12.036	0.17165	0.14826	0.211
	TM	10.1699	0.04756	0.047629	0.079

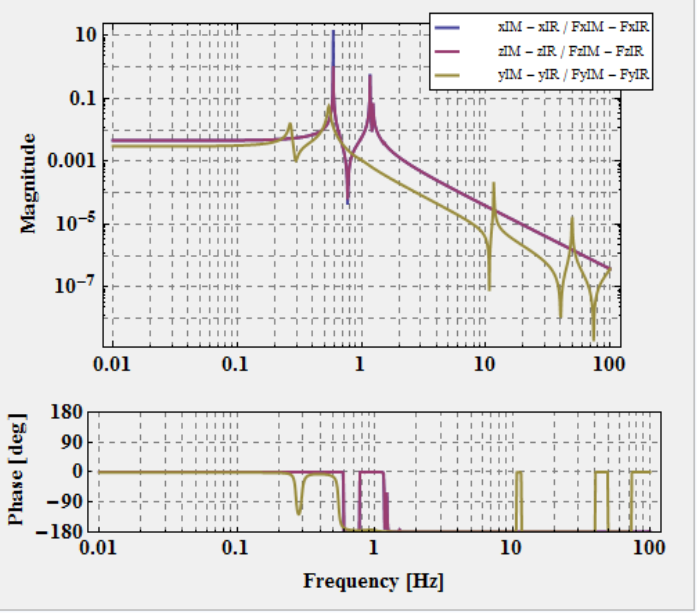
Step 2. Define Connections

Set Material Properties
2–1 Define Wires
2–2 Define Vertical Springs

Wire:

Name	Body1	Body2	Material	L [m]
F0–MD–1	F0	MD	Maraging Steel	0.954811
F0–MD–2	F0	MD	Maraging Steel	0.954811
F0–MD–3	F0	MD	Maraging Steel	0.954811
F0–F1–1	F0	F1	Maraging Steel	1.27762
F1–F2–1	F1	F2	Maraging Steel	0.512716

Open New Window



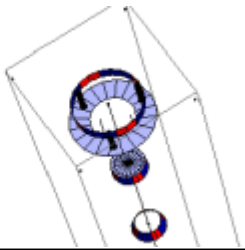
Add Plot | Clear Plot

Show Legend
Set x–range {0.01, 100.}
Set y–range {1.×10^-10, 100.}

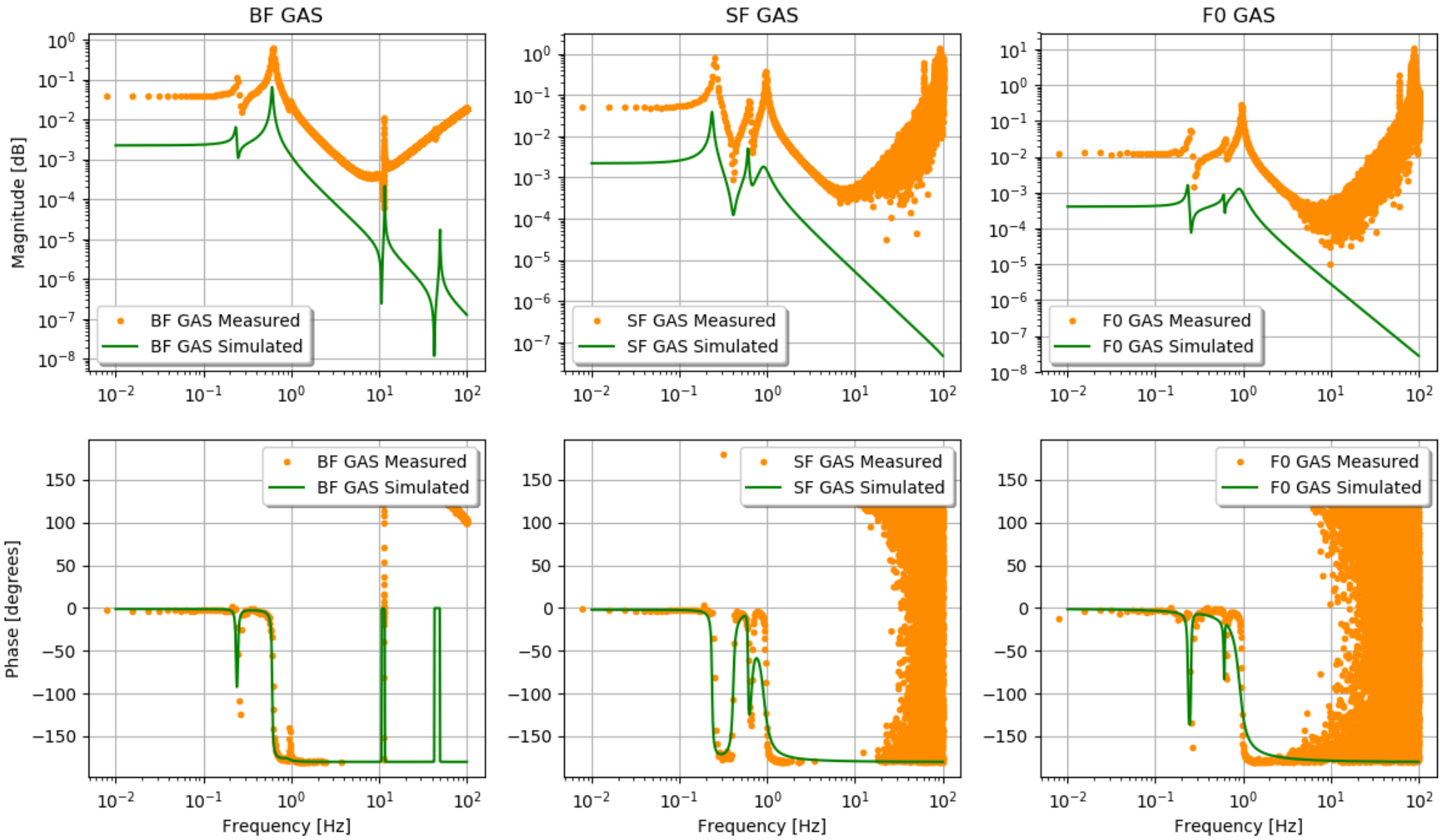
xIM - xIR / FxIM - FxIR Line
zIM - zIR / FzIM - FzIR Line
yIM - yIR / FyIM - FyIR Line

Sum | x Factor | Inverse | Multiply | RMS
Hide | Show | Delete | Save | Load
Export | Import

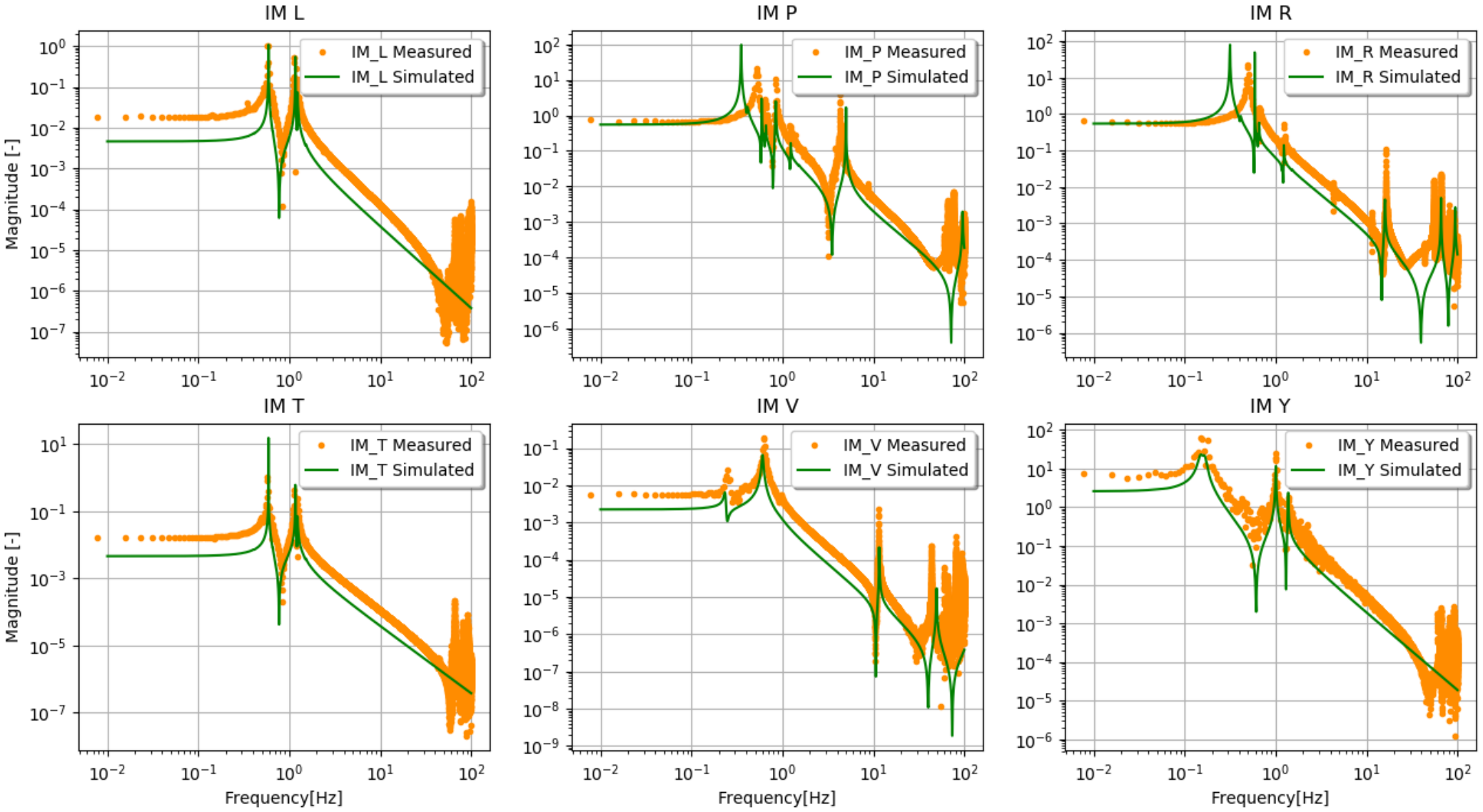
SUMCON in Mathematica
spension odel structor



SR2: Measured TF of GAS filters (Vertical) in the assembly frame

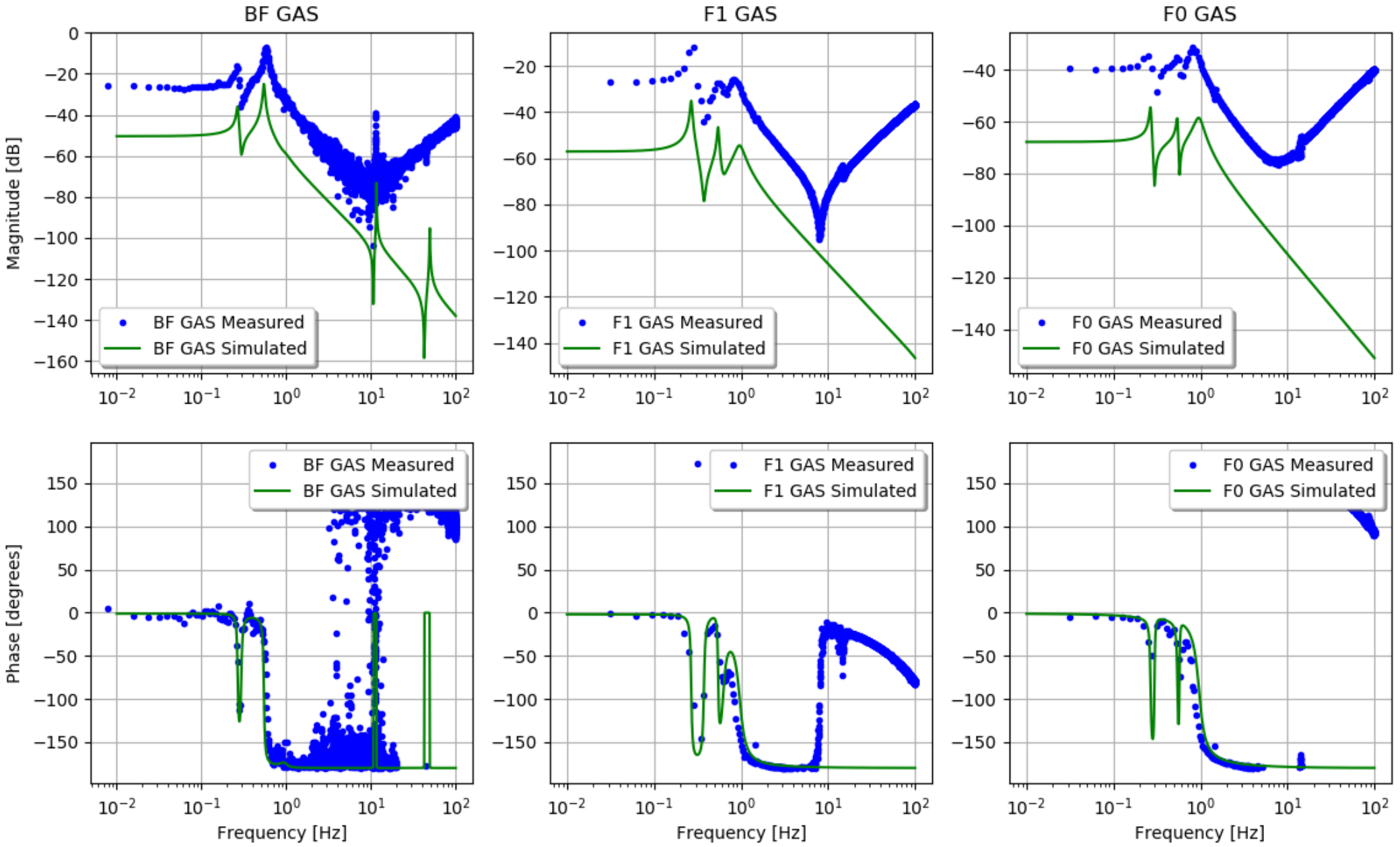


SR2: Measured TF of L, P, R, T, V and Y of the IM in the assembly frame

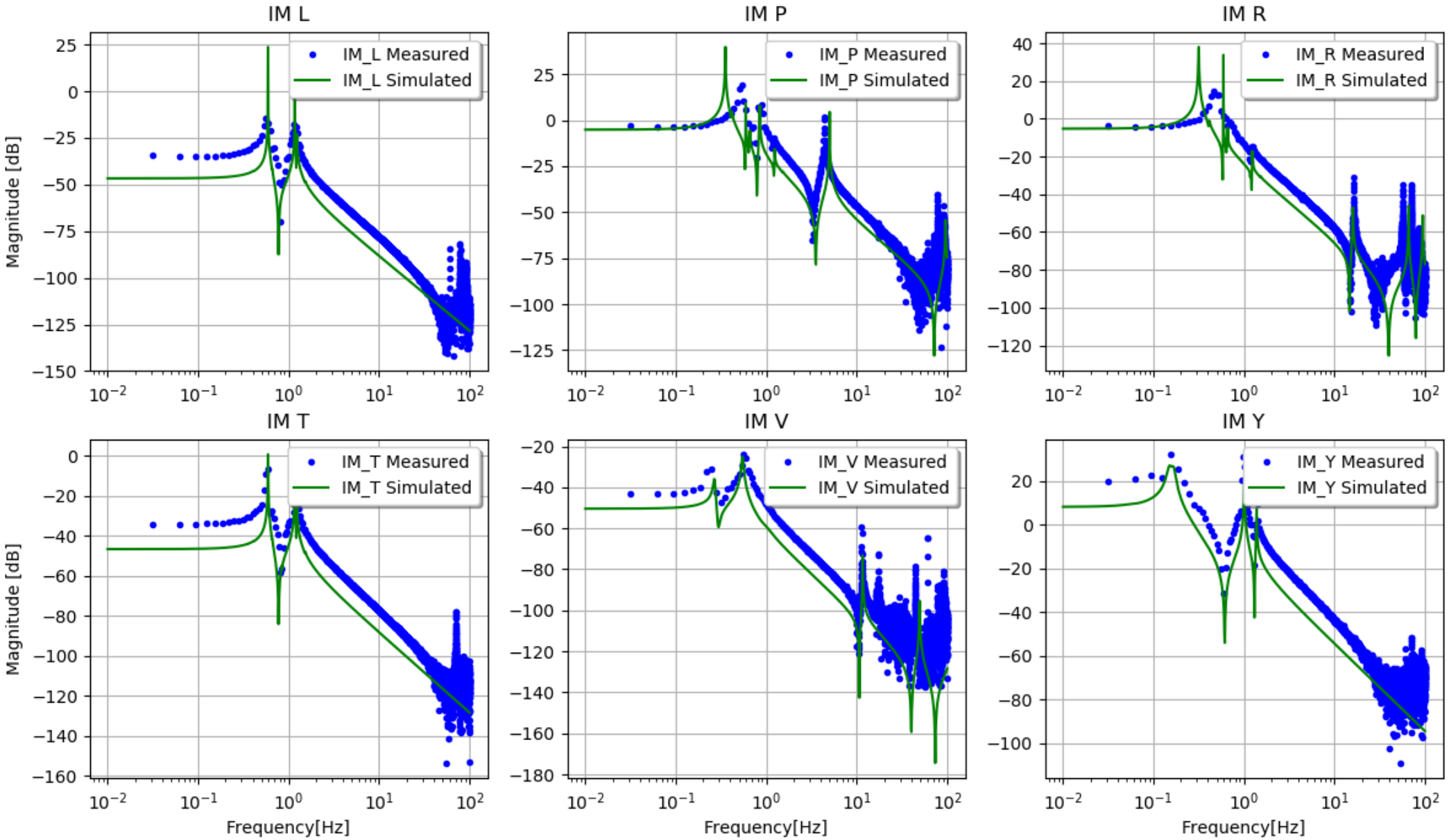


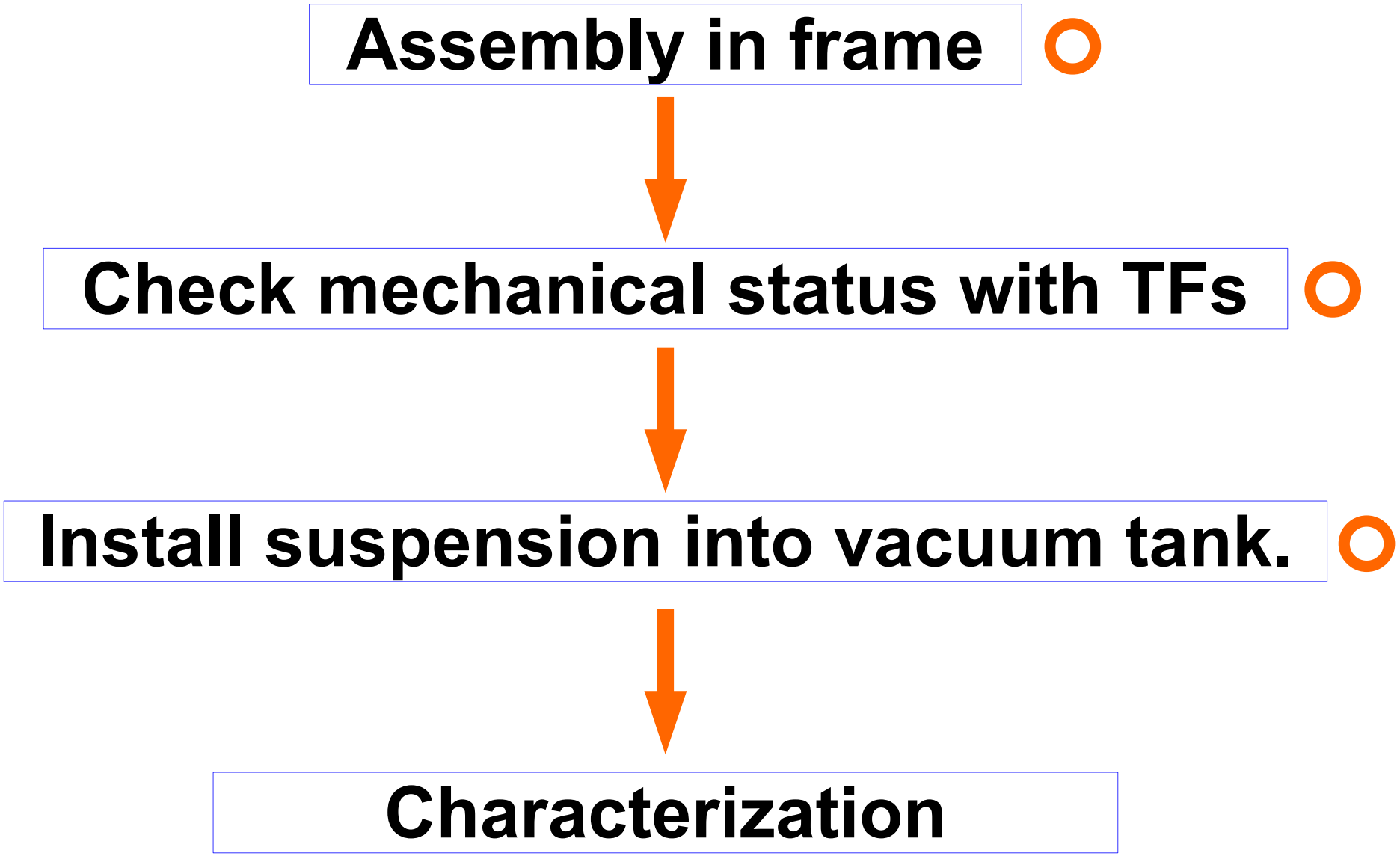
SR3 installated

SR3: Measured TF of GAS filters (Vertical) in the tank



SR3: Measured TF of L, P, R, T, V and Y of the IM in the tank




Assembly in frame
Check mechanical status with TFs
Install suspension into vacuum tank.
Characterization

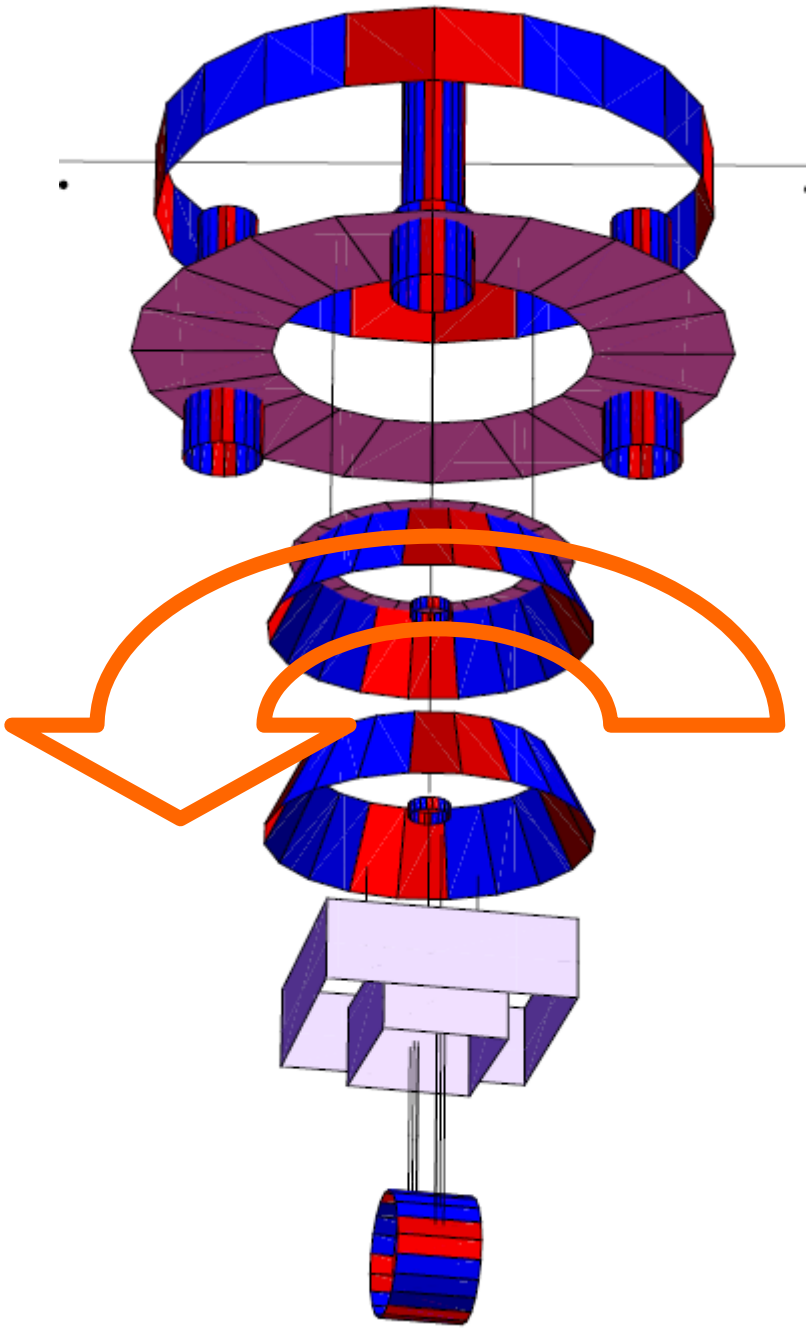
Eigenmodes identification using SUMCON

Requirements

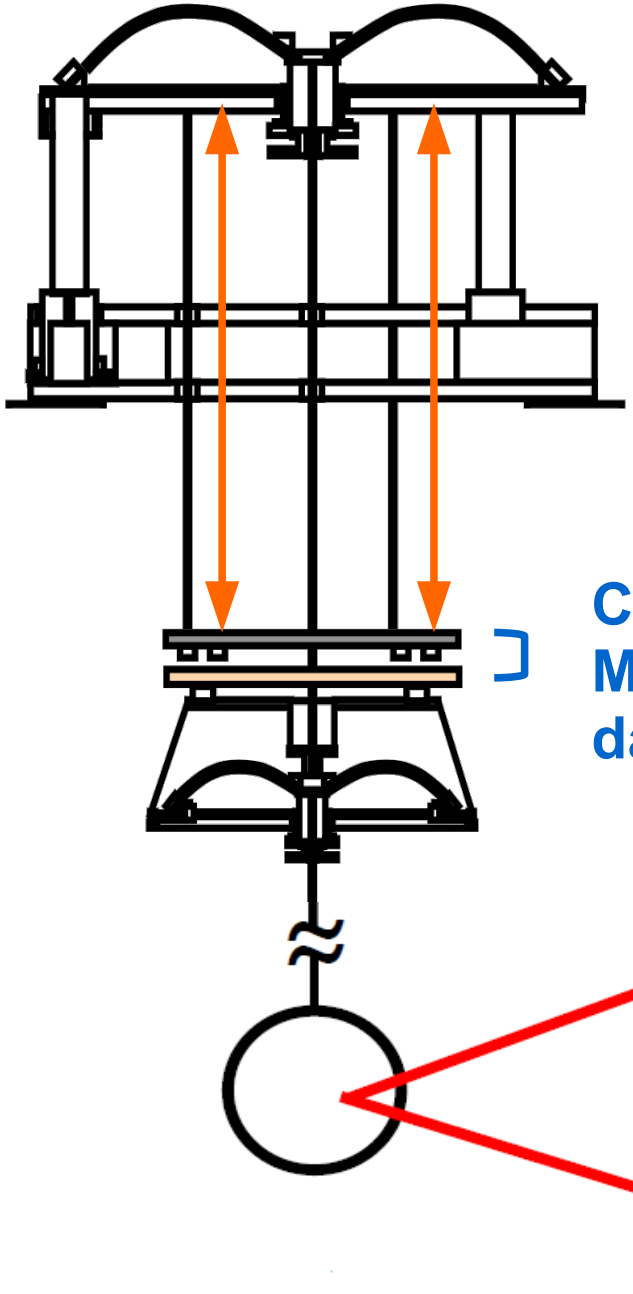
The alignment of the optic has to be recovered soon enough.

Decay time < 60 [s]
for all the modes.

Eigen-mode # 1 (torsion of the whole suspension)



Damping of the Torsion mode

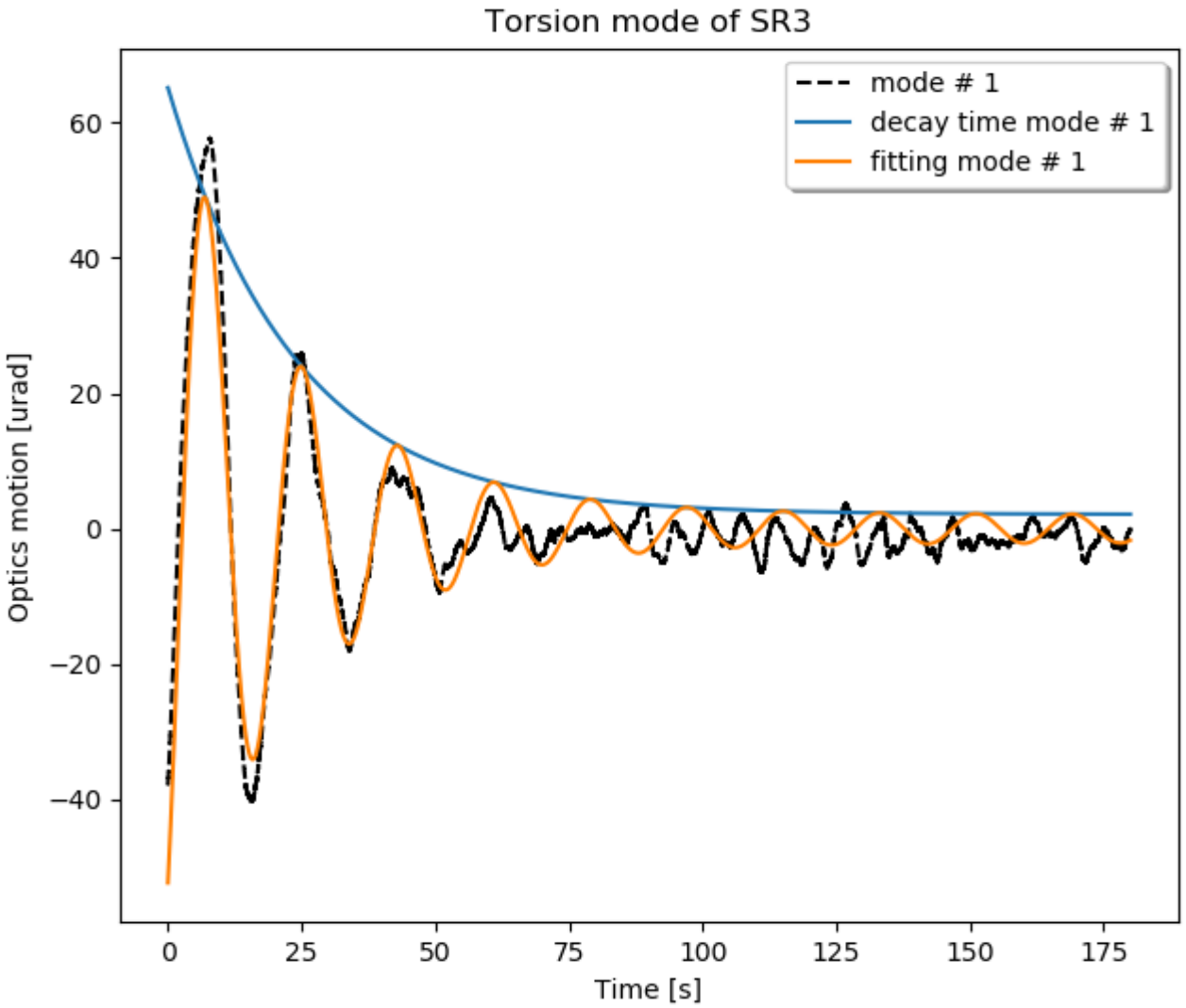


Adjust the height of the MD by lifting the rods.

Change distance between MD ring and SF to tune the damping for this mode

Measure motion of the mirror with the optical lever.

Damping of the Torsion mode



Decay time <60[s]

Freq. Simulation: 0.0542 [Hz]

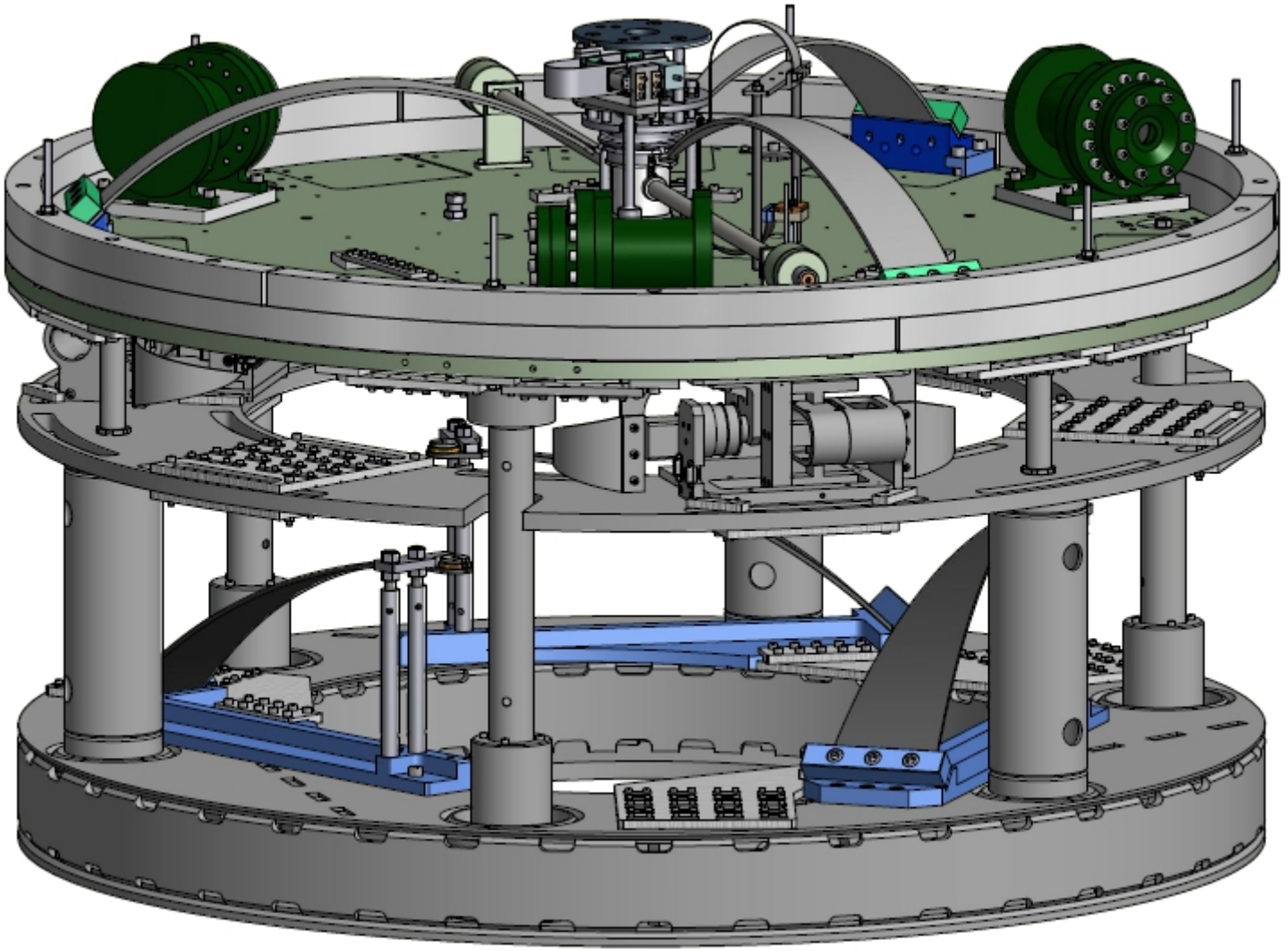
Freq. Measured: 0.0555 [Hz]

This is only the first mode, so we still have a long eigenmode list to check...

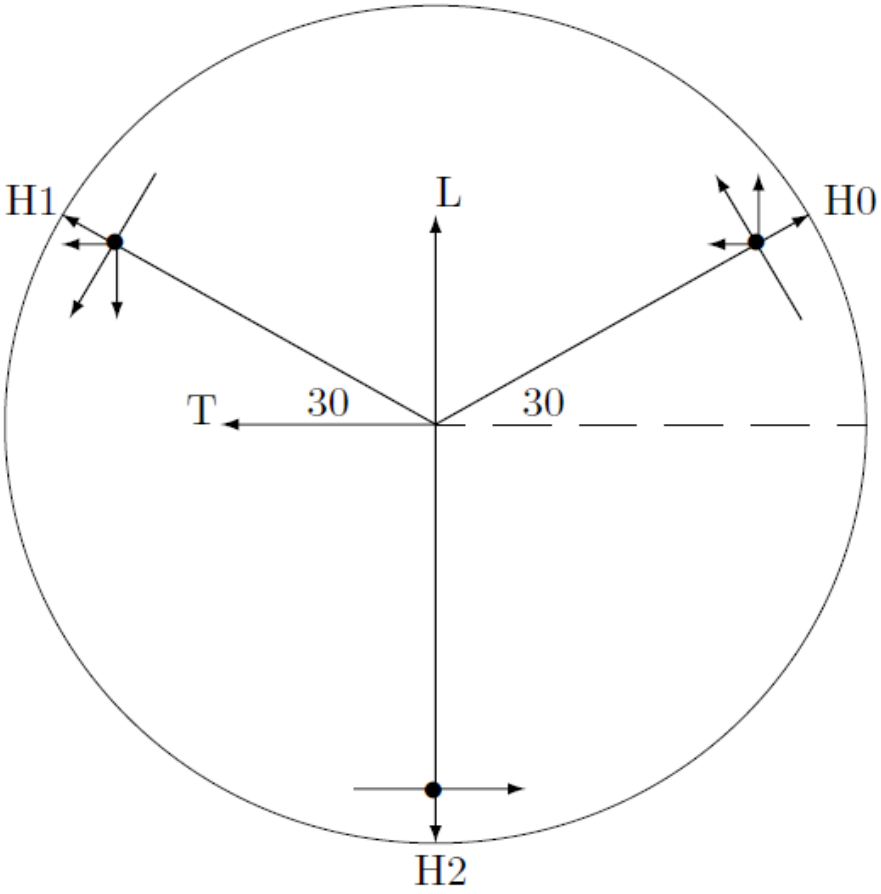
Diagonalization  **Characterization**

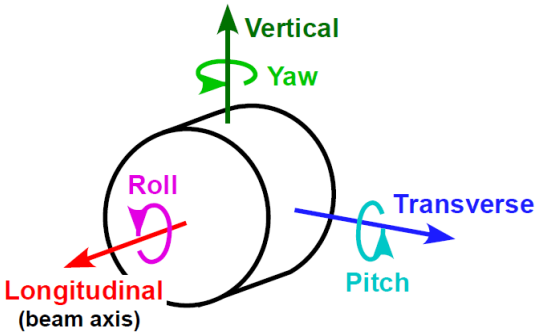
To reduce the cross-coupling between different DoF.

SR Preisolator (PI)

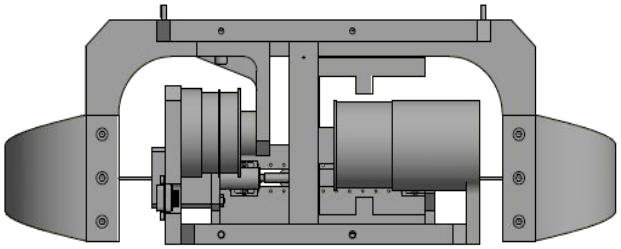


IP Sensor / Actuator diagonalization



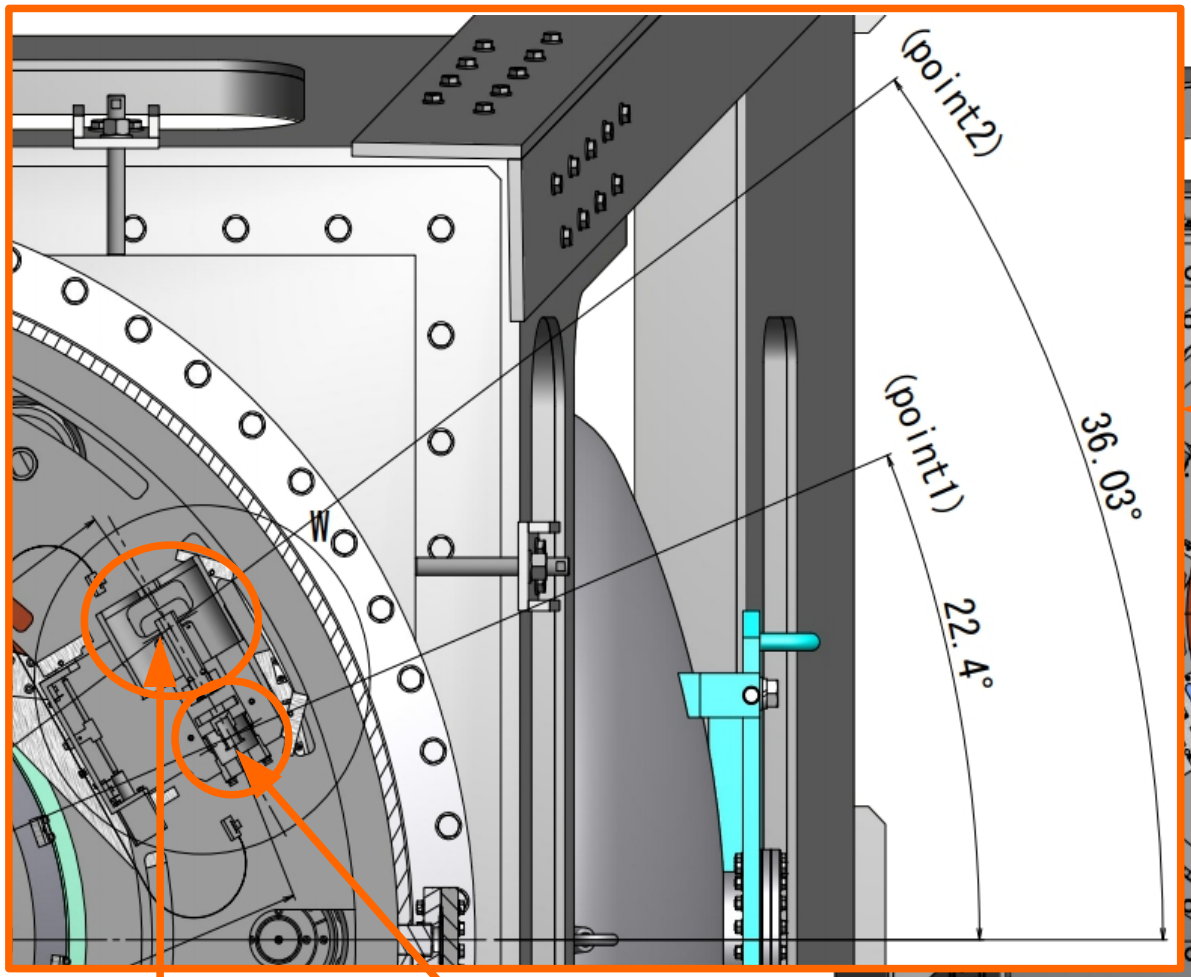


First approximation:
LVDT Sensors and actuators of Inverted pendulum (IP) at the same position.

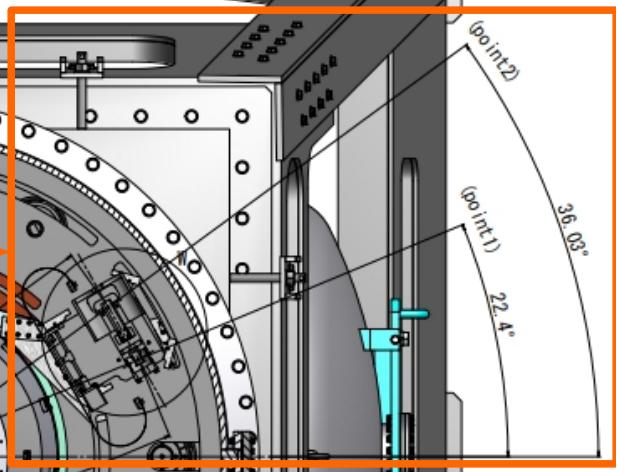


In reality:
Compare CAD model with the measured position.

IP Sensor / Actuator diagonalization



Top view



Actuator

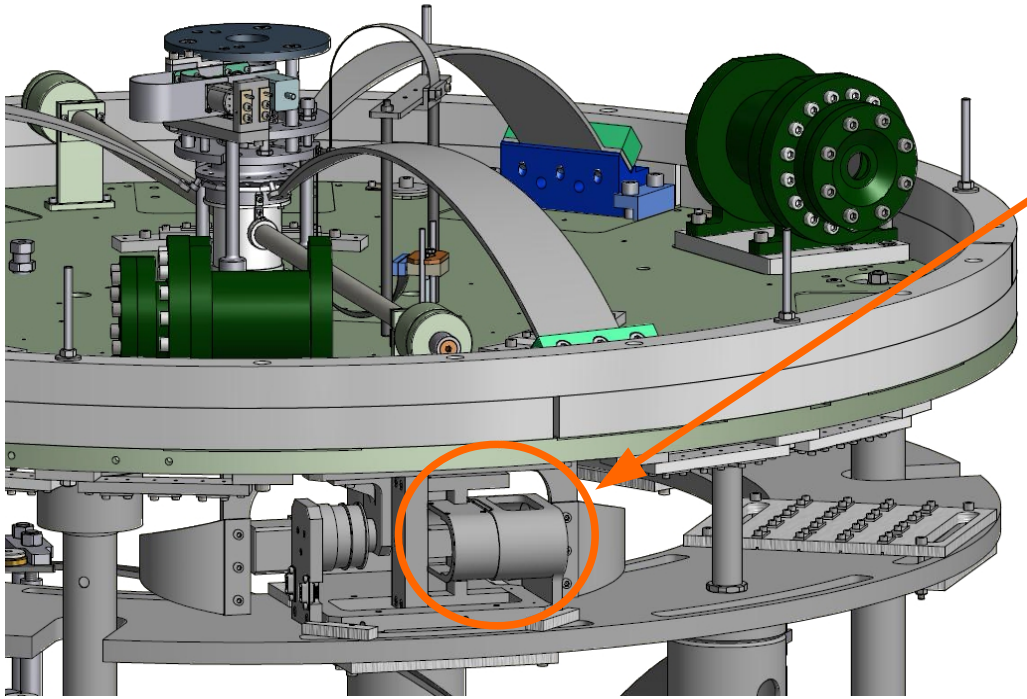
Sensor

For the sensing matrix the position of the sensor is used.
We assume that the sensing is accurate there.

Useful gap for diagonalization.

#29	1.1709	-PF2, -LIR, -PIR, LIM, -PIM, -LRM, -PRM, -LTM.	IM pendulum
#30	1.2342	PF2, RF2, -TIR, LIR, PIR, RIR.	F2 pitch roll
#31	1.2354	-PF2, RF2, -TIR, -LIR, -PIR, RIR.	F2 pitch roll
#32	1.3749	YIM, -YRM, -YTM.	TM yaw
#33	1.5232	TF1, -LF1, PF1, RF1, -TF2, LF2, -PF2, -RF2, TIR, -LIR, -PIR, -RIR, TIM, -LIM.	pendulum
#34	1.5265	-TF1, -LF1, PF1, -RF1, TF2, LF2, -PF2, RF2, -TIR, -LIR, -PIR, RIR, -TIM, -LIM.	pendulum
#35	5.0066	-PIM, PRM.	RM pitch
#36	11.6131	-VIM, -VRM, VTM.	GAS, or TM vertical
#37	15.9279	RRM, -RTM.	TM roll
#38	49.472	-VIM, VRM.	IM vertical
#39	52.0648	VMD.	MD vertical
#40	52.4298	PMD.	MD pitch
#41	52.4634	-RMD.	MD roll

IP Sensor / Actuator diagonalization

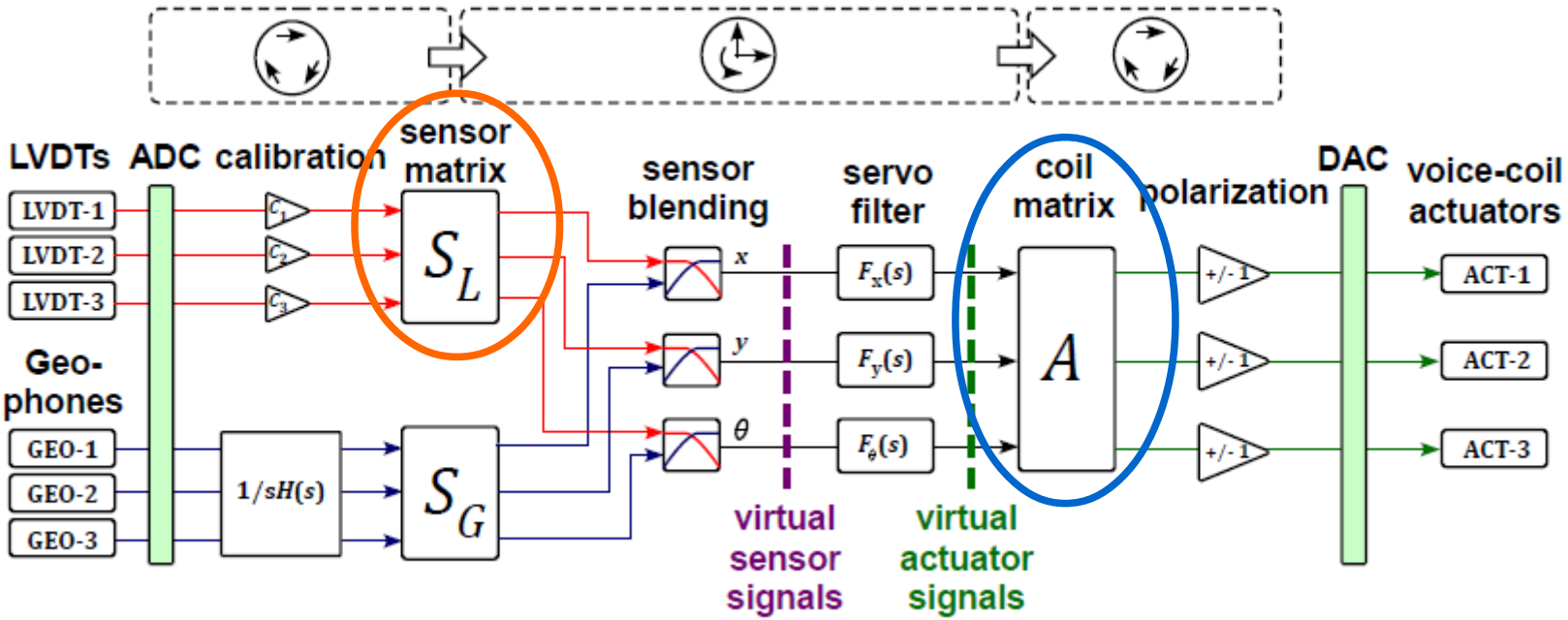


Inject a sinusoidal signal at a single frequency in the 'safety band' in each of the actuator coils.

Measure the motion of the inverted pendulum stage in L, T and Y using the sensing matrix.

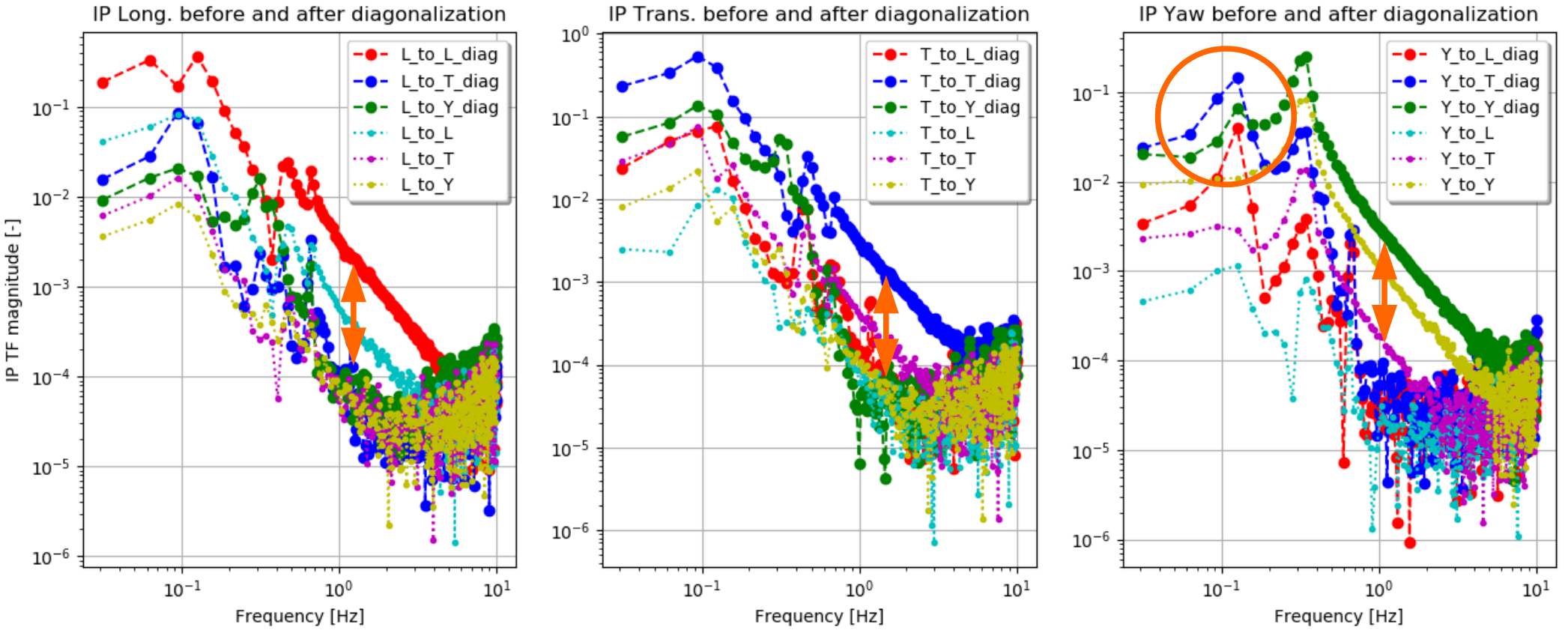
Get the coefficients for L, T and Y from the force applied at each of the coils and write down the TF matrix.

IP Sensor / Actuator diagonalization



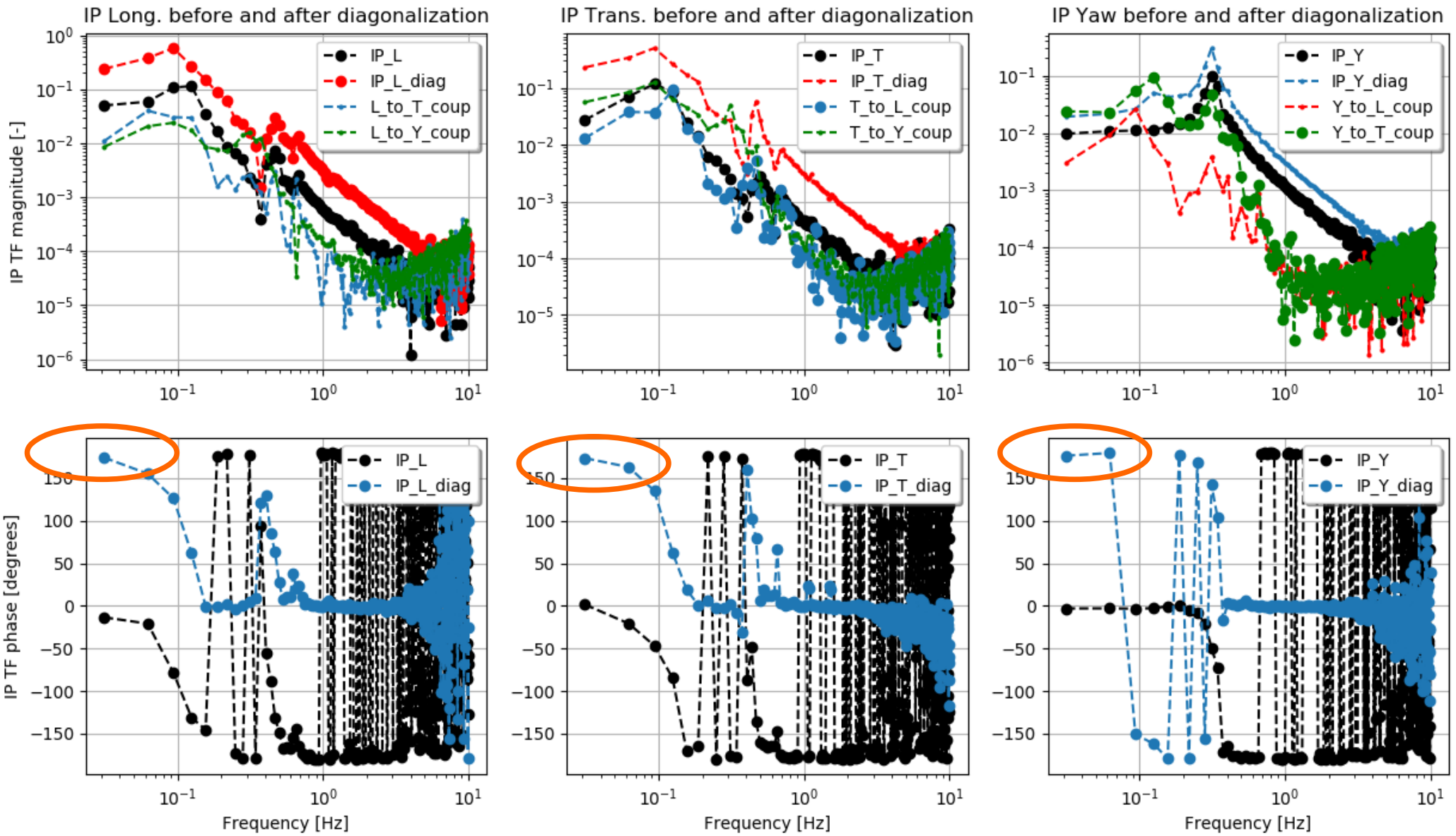
Then, by taking the inverse of the TF matrix, and if necessary, converting the units, we complete the diagonalization of the system. And we use this last matrix as the new coil matrix.

Measured TF of Longitudinal, Transverse and Yaw of the SR3 IP



This first diagonalization reduces the coupling to other DoF, but is not sufficient. It must be improved.

Measured TF of Longitudinal, Transverse and Yaw of the SR3 IP



Future work

Hardware:

- Install Length sensing oplev.
- Adjust height of MD ring of SR2.
- Take TF of the top stage to check health status of the suspension.
- Install SR2 inside the tank.
- Continue assembly of SRM.

Software:

- Improve diagonalization of the PI and include Geophone signals.
- Identification of other modes of SR3 and implement damping filters.
- Measure decay time of all the modes.
- Measure RMS of velocity and angular fluctuation of the mirror .
- Characterization of SR2 and SRM.

KAGRA

国立天文台 NAOJ National Astronomical Observatory of Japan

Thank you!