CLIC Module Stability Requirements

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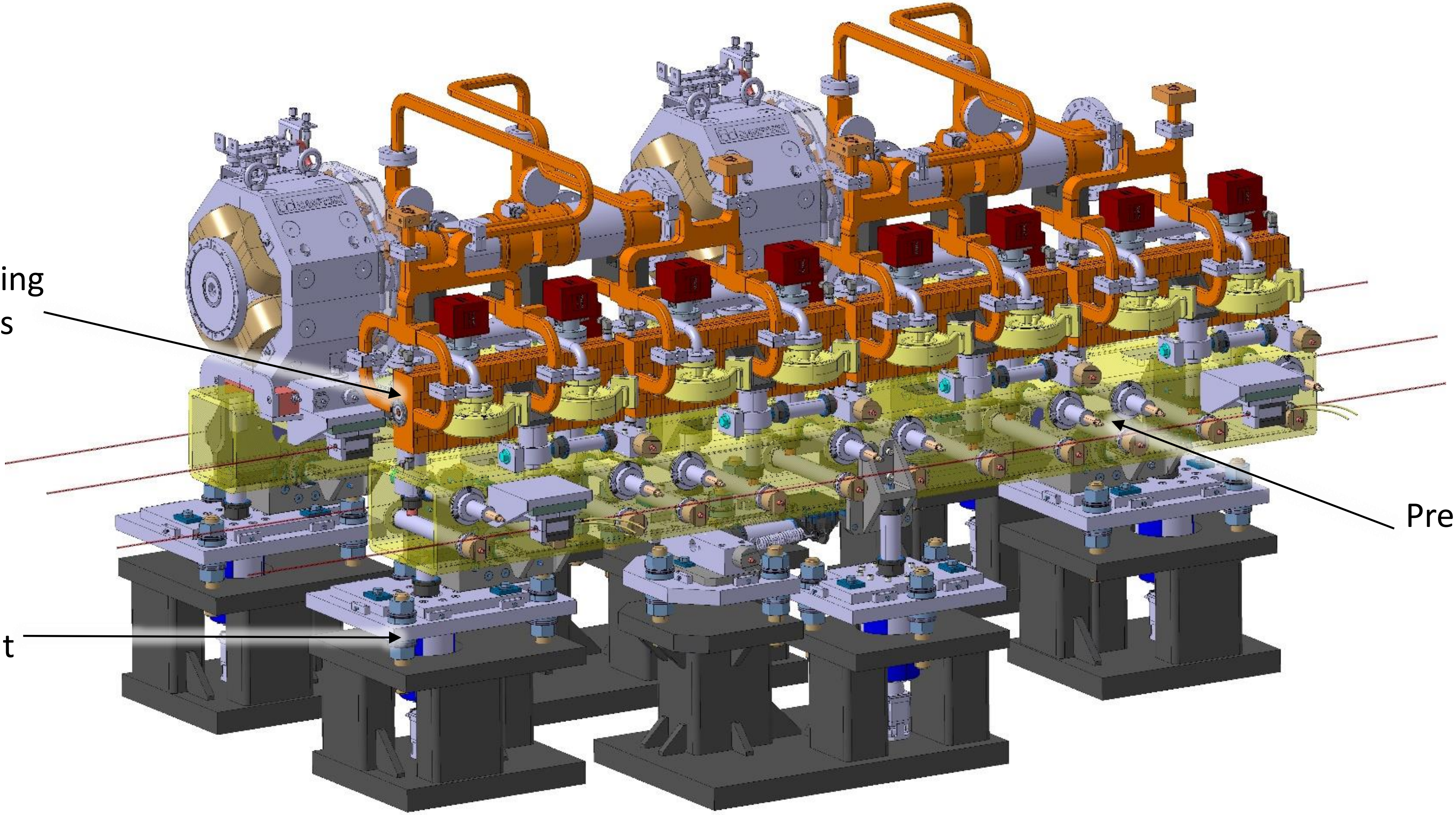
Two Beam Module Design



Accelerating Structures

Prealignment System

Active Alignment System

Position Requirements

Structure Alignment Requirements (PIP)

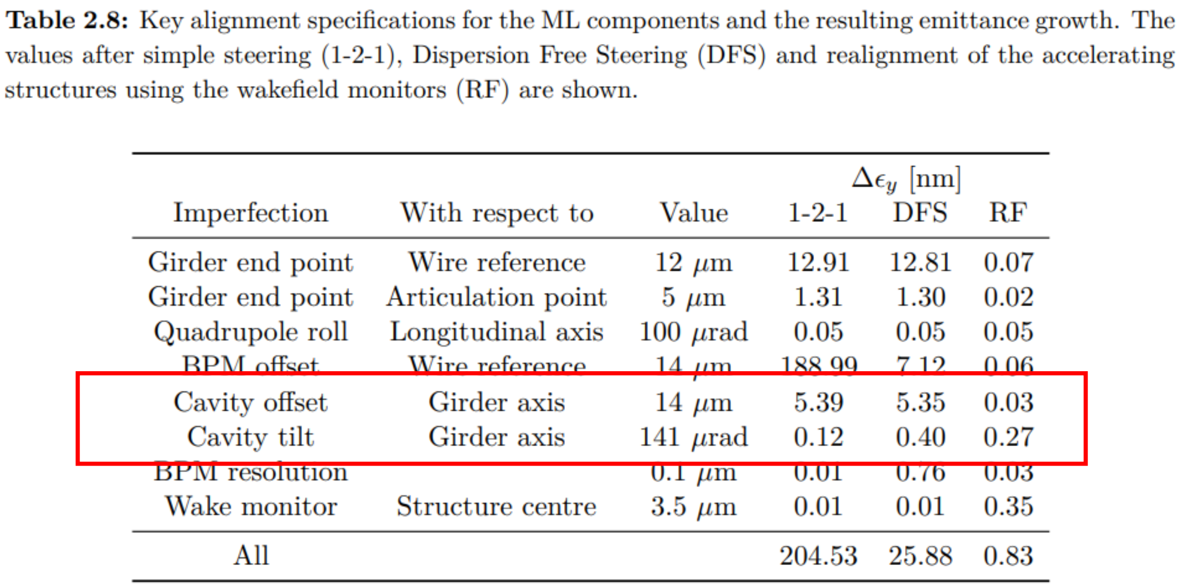
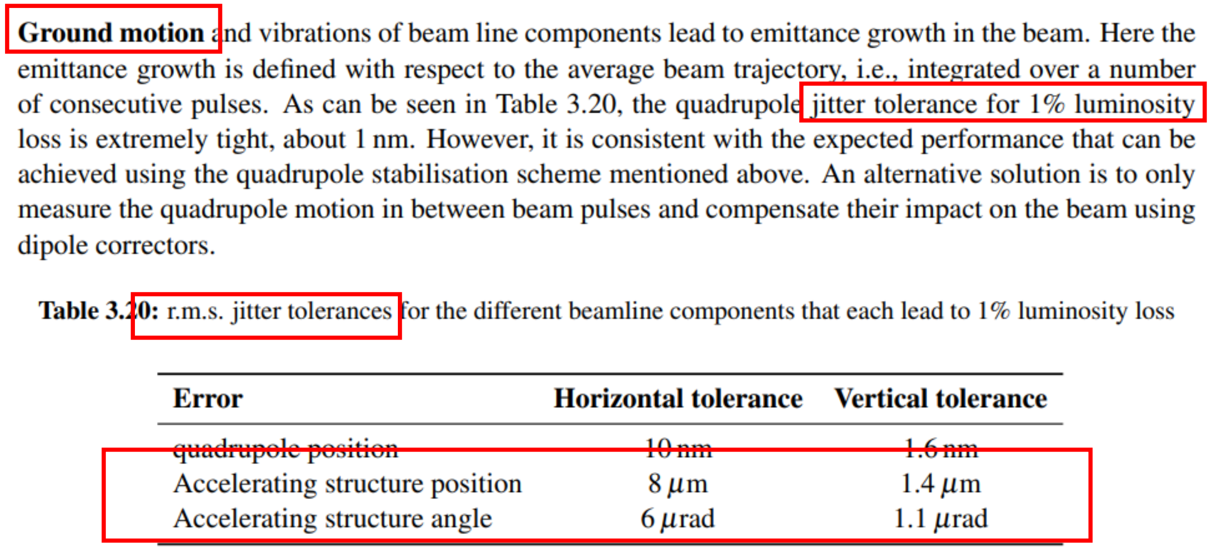


Table 2.8: Key alignment specifications for the ML components and the resulting emittance growth. The values after simple steering (1-2-1), Dispersion Free Steering (DFS) and realignment of the accelerating structures using the wakefield monitors (RF) are shown.

Imperfection	With respect to	Value	$\Delta\epsilon_y$ [nm] 1-2-1	 DFS	 RF
Girder end point	Wire reference	12 μm	12.91	12.81	0.07
Girder end point	Articulation point	5 μm	1.31	1.30	0.02
Quadrupole roll	Longitudinal axis	100 μrad	0.05	0.05	0.05
BPM offset	Wire reference	14 μm	188.99	7.12	0.06
Cavity offset	Girder axis	14 μm	5.39	5.35	0.03
Cavity tilt	Girder axis	141 μrad	0.12	0.40	0.27
BPM resolution		0.1 μm	0.01	0.76	0.03
Wake monitor	Structure centre	3.5 μm	0.01	0.01	0.35
All			204.53	25.88	0.83

Structure Jitter Requirements (CDR)



Ground motion and vibrations of beam line components lead to emittance growth in the beam. Here the emittance growth is defined with respect to the average beam trajectory, i.e., integrated over a number of consecutive pulses. As can be seen in Table 3.20, the quadrupole jitter tolerance for 1% luminosity loss is extremely tight, about 1 nm. However, it is consistent with the expected performance that can be achieved using the quadrupole stabilisation scheme mentioned above. An alternative solution is to only measure the quadrupole motion in between beam pulses and compensate their impact on the beam using dipole correctors.

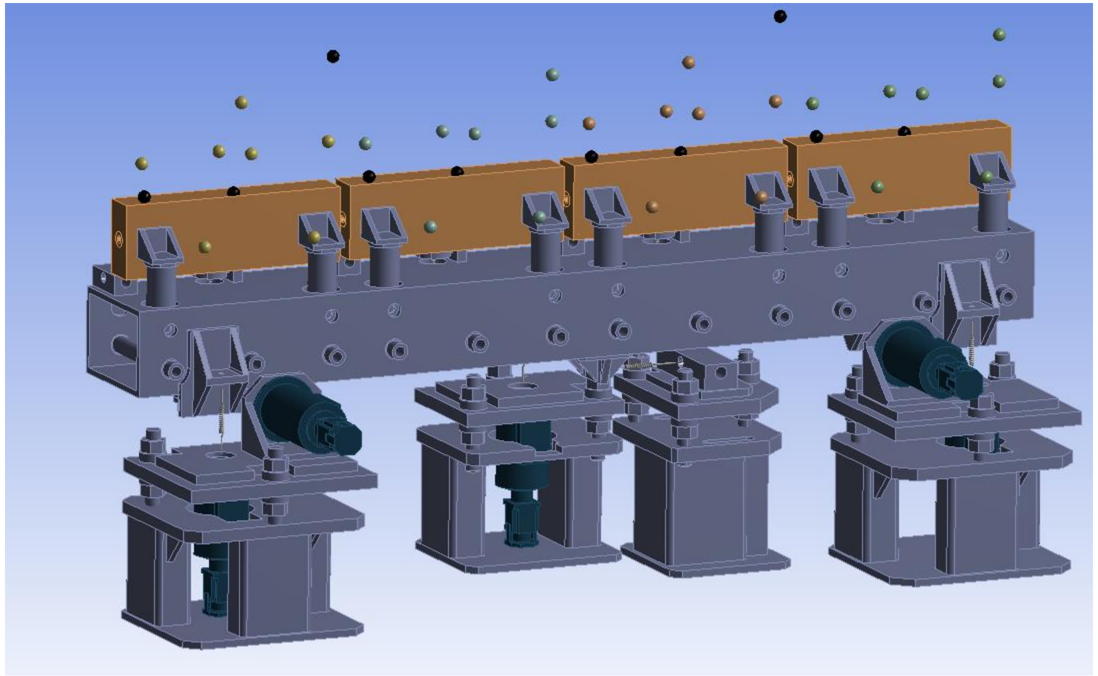
Table 3.20: r.m.s. jitter tolerances for the different beamline components that each lead to 1% luminosity loss

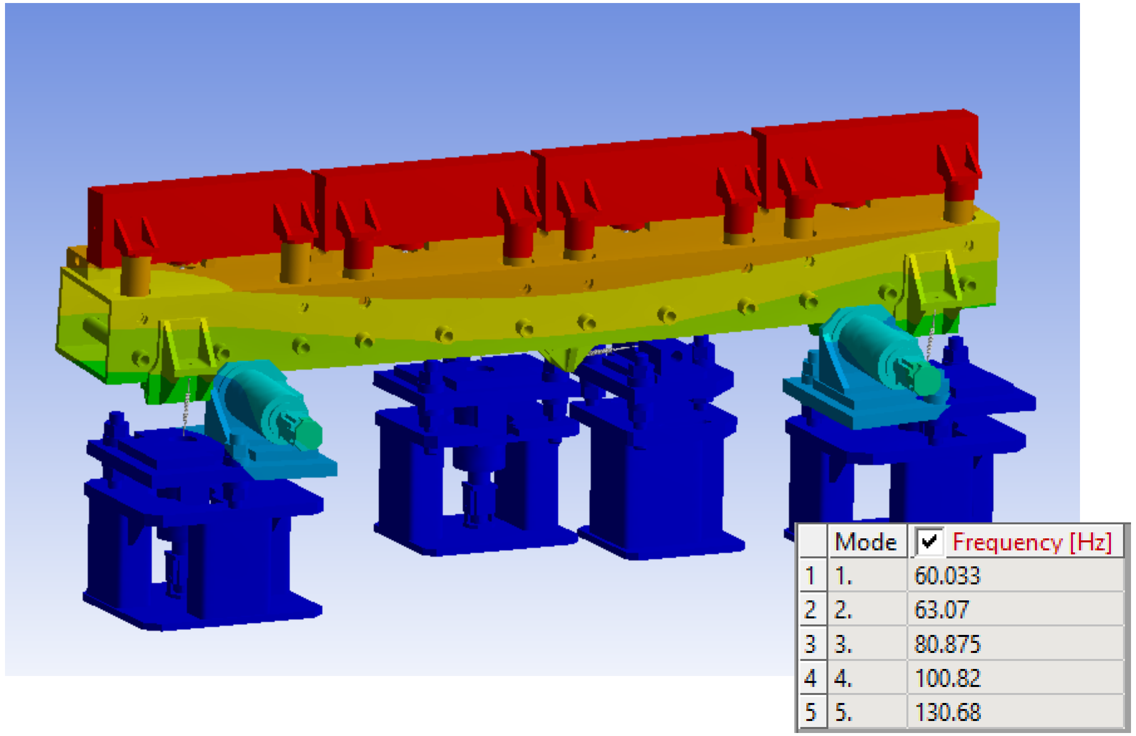
Error	**Horizontal tolerance**	**Vertical tolerance**
quadrupole position	10 nm	1.6 nm
Accelerating structure position	8 μm	1.4 μm
Accelerating structure angle	6 μrad	1.1 μrad

Finite Element Analysis Performed

- **Static Structural**
    - Calculation of static deformation of the girder, i.e. structure position
- **Modal Analysis**
    - Determine the harmonic frequencies and to identify ones which pose a risk to the stability requirements:
        - e.g. close to 50Hz, ones which cannot be corrected by BBA, low frequencies affected by GM
    - Cannot directly compare these results to the stability requirement
        - No applied load/excitation
- **Random Vibration**
    - A spectrum analysis technique which calculates the probability distribution of different results, such as displacement, due to some random excitation, using the combined effects from each harmonic mode.
        - Commonly used for jitter in alignment of optical equipment.
    - Assumes a Gaussian distribution of results.
    - Takes a Power Spectral Density function as the input: e.g. ground noise data.

Module Modal Analysis

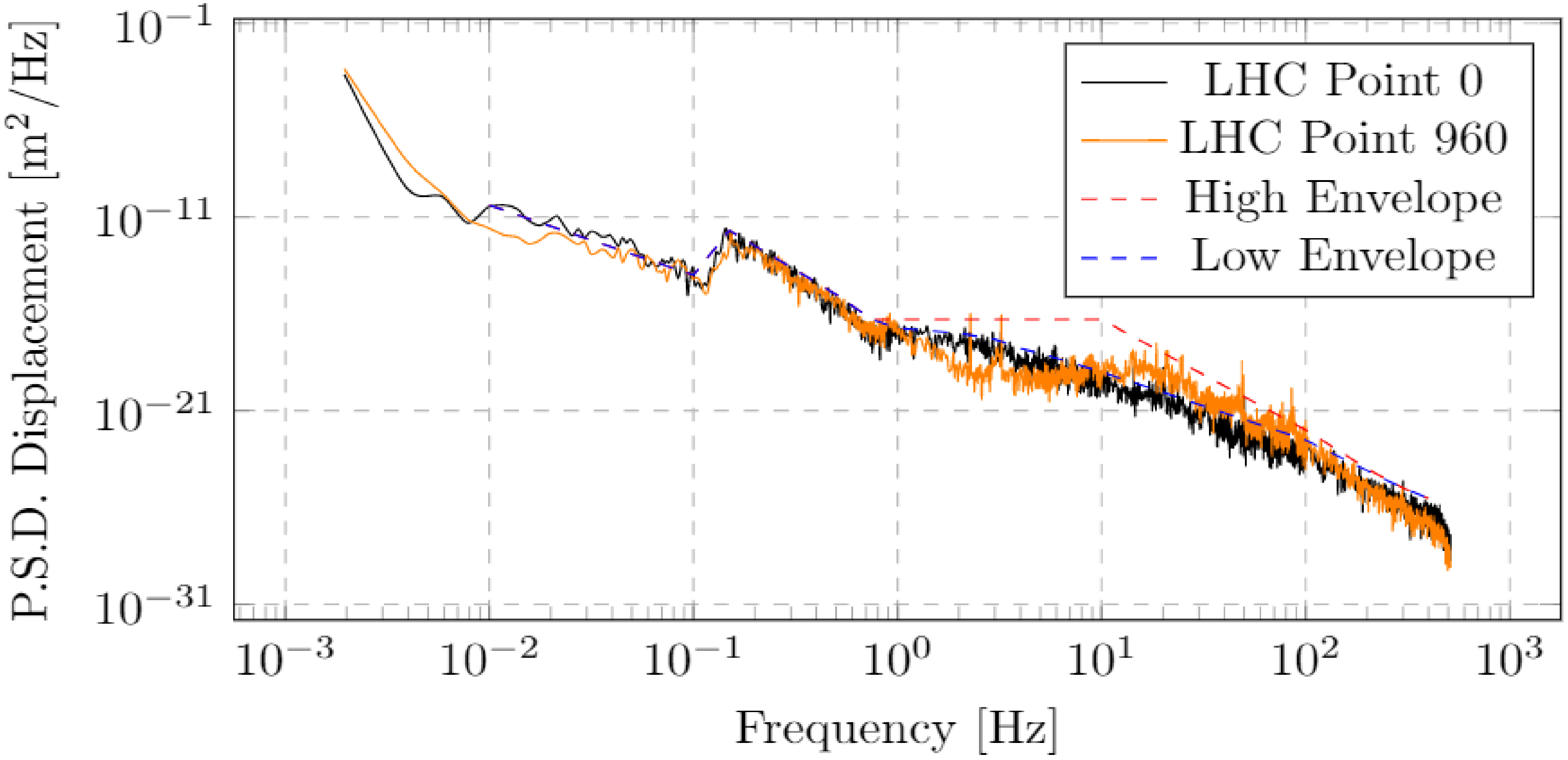




	Mode	☑ Frequency [Hz]
1	1.	60.033
2	2.	63.07
3	3.	80.875
4	4.	100.82
5	5.	130.68

LHC Ground Noise Data

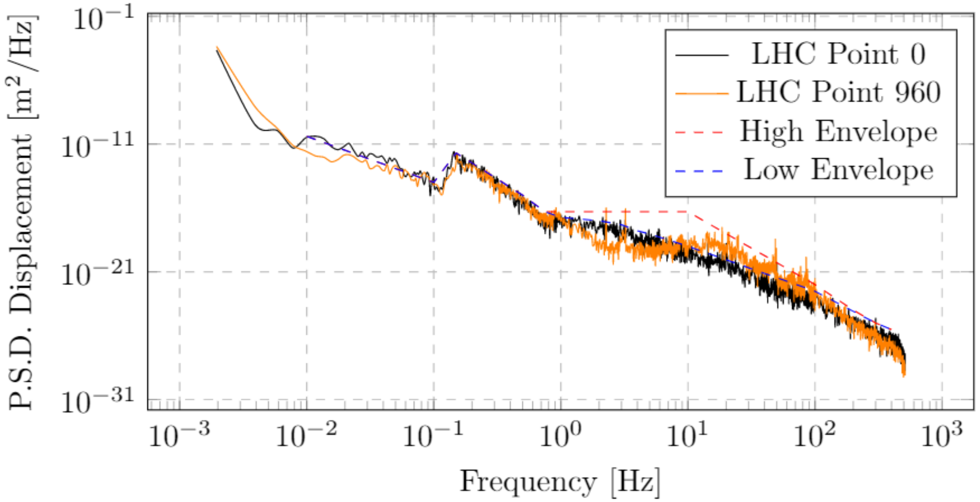
- Data we have ranges from ~0.002 Hz – 500Hz



What is the relevant frequency range?

- ***CLIC PIP: 5.10.2 Ground Motion Content***:
  - Below 1 Hz vibrations are dominated by the earth motion like the micro-seismic peak at 0.17 Hz which is due to incoming sea waves.
  - Above 1 Hz, the cultural noise level depends on the proximity to internal systems or cryogenic pumps for example.

LHC Ground Noise Displacement Power Spectral Density (PSD)



Including the very low frequency ground noise data results in very large standard-deviation displacements.

Coherence of Ground Noise

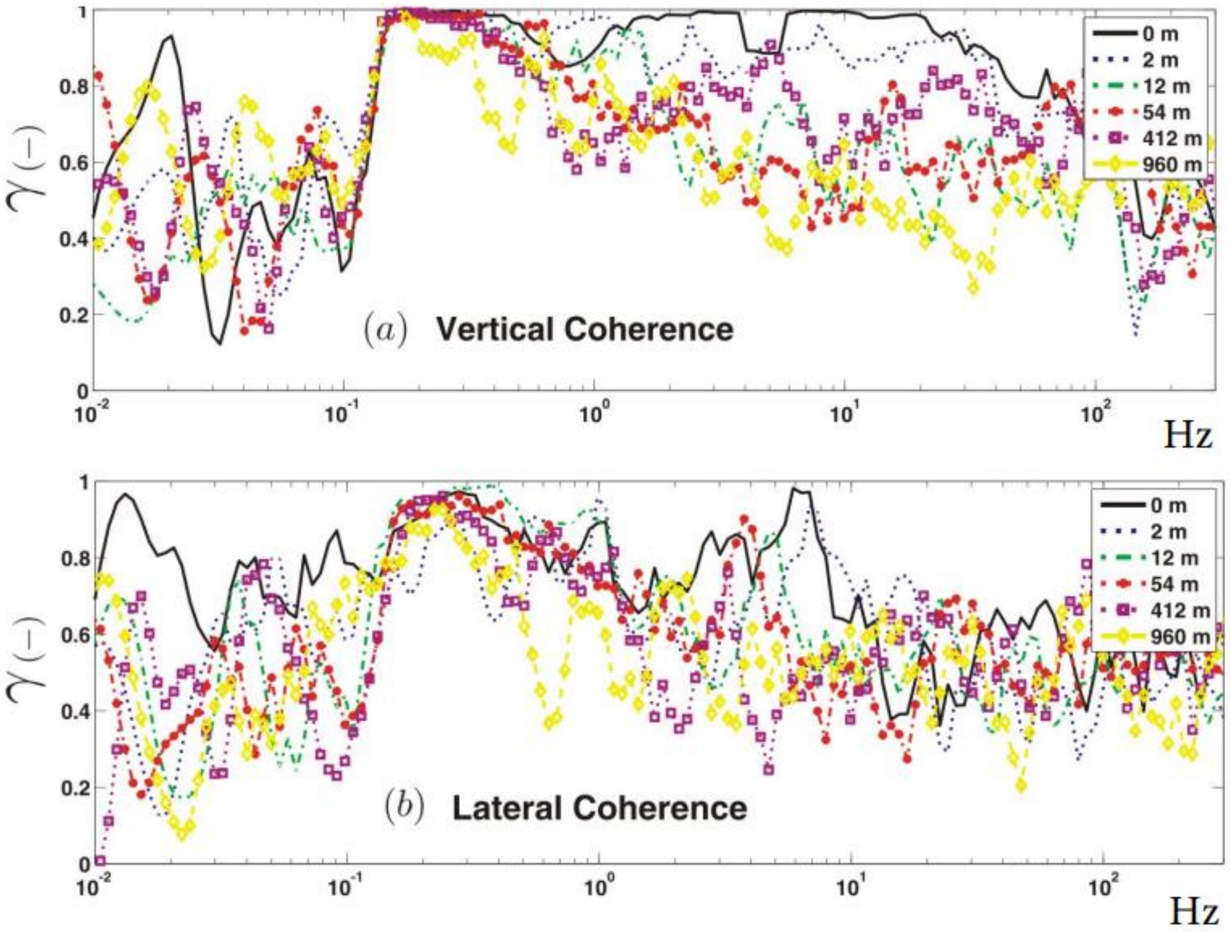


Figure 5.29: Coherence measured in vertical and lateral directions [85].

PSD Output Response

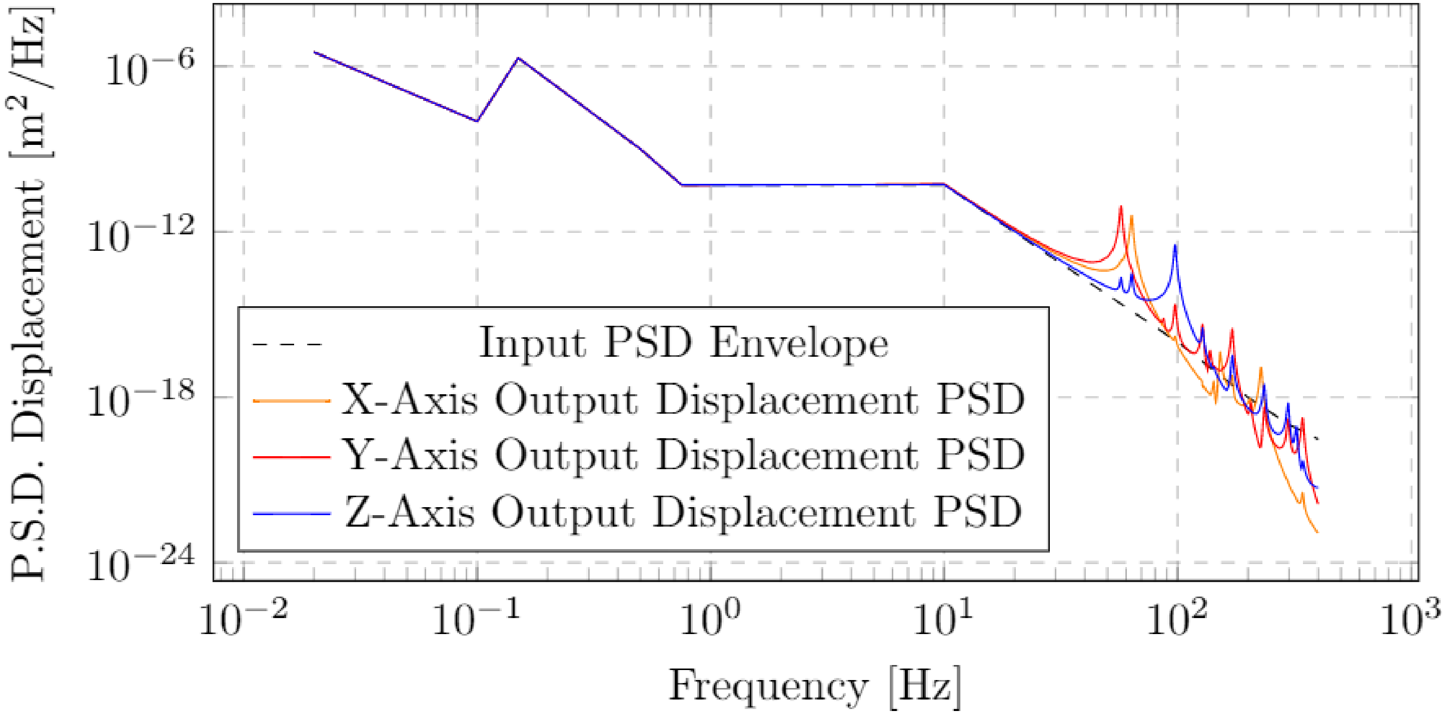


Figure 16: Power Spectral Density of module response due to known ground noise.