European Organization for Nuclear Research

LCWS11

Pre-isolation R&D

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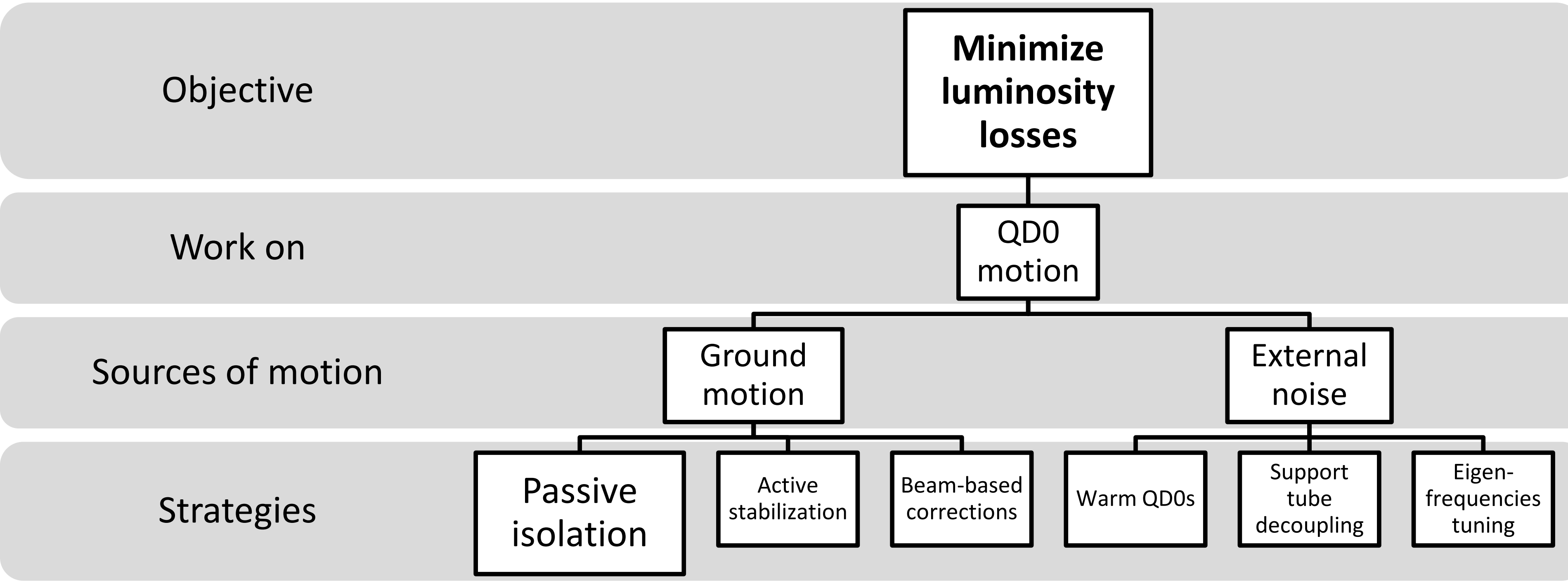
Introduction



Stability requirements at QD0 (r.m.s. above 4Hz):

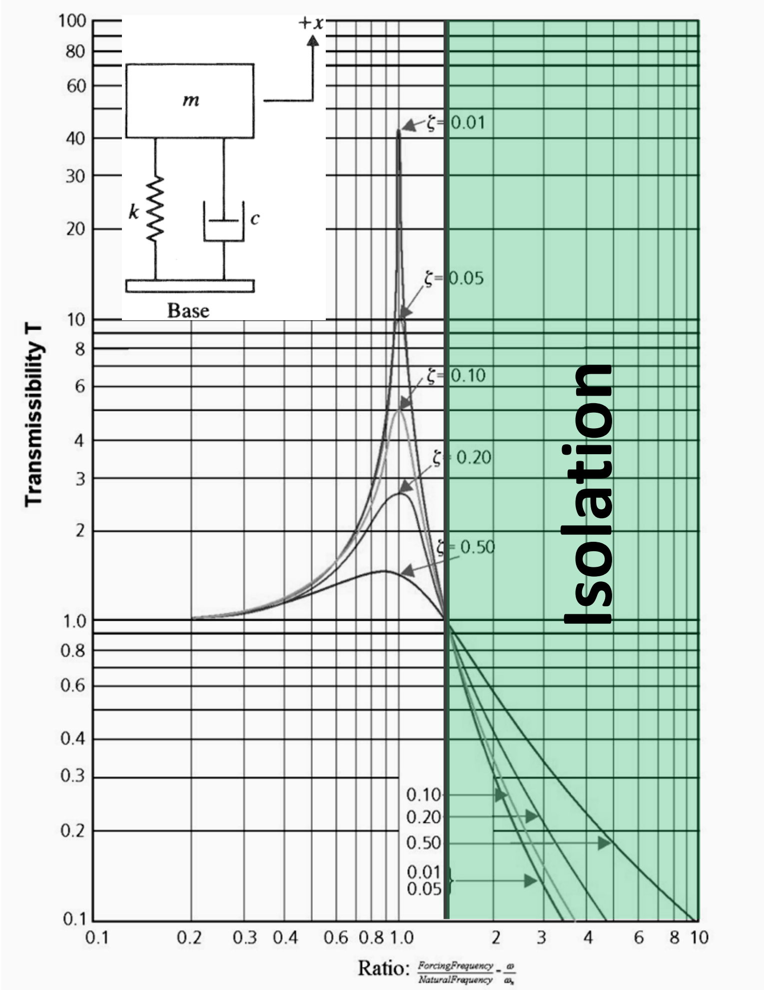
Vertical	Horizontal
0.15 nm	5 nm

Passive isolation

- The simplest approach: consists of resilient member (stiffness) and an energy dissipator (damping);

- Works as a low-pass filter for ground motion;

- Widely used approach for the first “layer” of vibration isolation in nanotechnology labs;

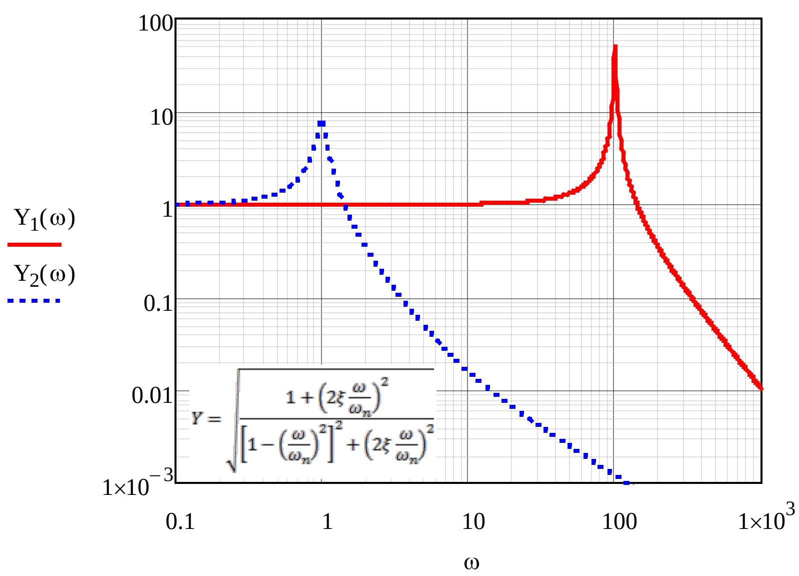


1-DOF analysis

Two options:

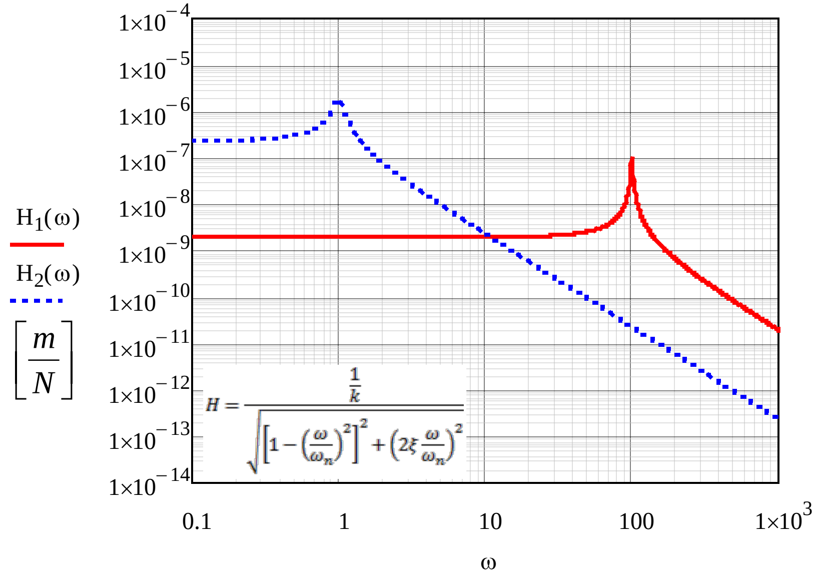
Hard mount (e.g. Support tube)				OR	Pre-isolator			
QD0 Mass (yoke)	Stiffness	ξ	ω_n		Pre-isolator (total mass)	Stiffness	ξ	ω_n
1.3 ton	5E8 N/m	0.01	100 Hz		110 ton	4E6 N/m	0.06	1 Hz

Isolation from ground motion



$$Y = \sqrt{\frac{1+\left(2\xi\frac{\omega}{\omega_n}\right)^2}{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2+\left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

Isolation from direct disturbances



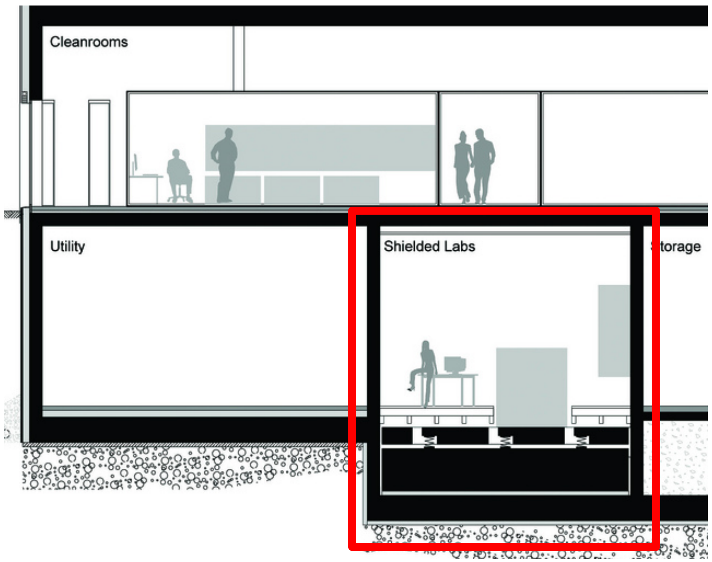
$$H = \frac{\frac{1}{k}}{\sqrt{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2+\left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

- Hard mount - would not contribute for the isolation from ground motion but would be resistant to direct disturbances in the whole frequency range;

- Pre-isolator – will isolate (above 1.4Hz) the system from ground motion and will be more immune to disturbances than an hard mount above 10 Hz; the very low frequency behaviour may need to be addressed depending on the requirements;

Examples of passive pre-isolators

IBM/ETH Nanotechnology Center
Zurich, Switzerland

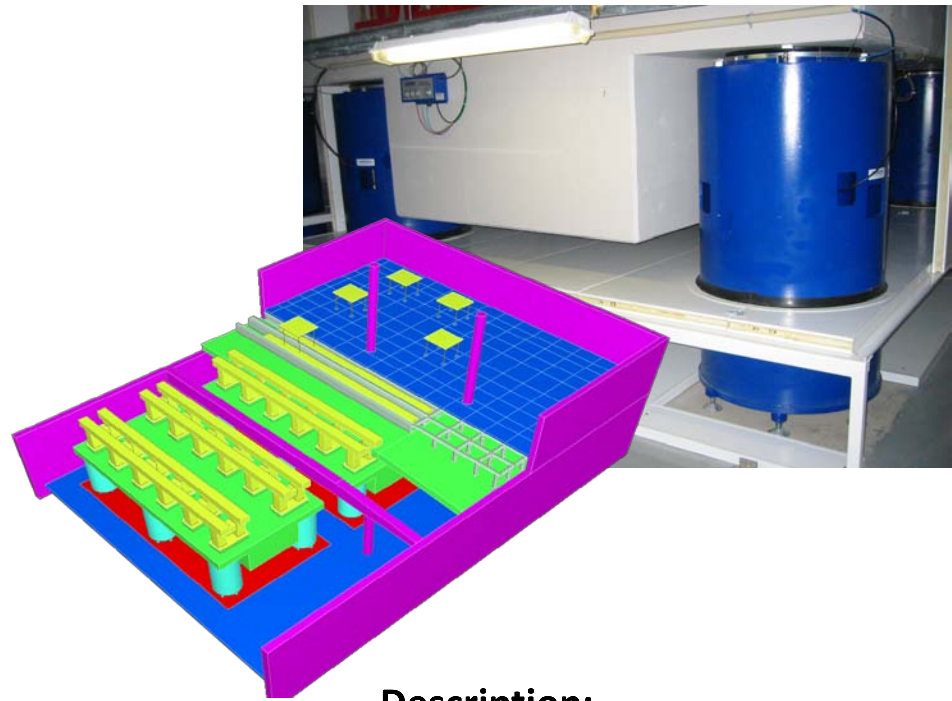


Description:

•Massive concrete pedestal (> 65 tons), suppressing frequencies above 25 Hz;

• Tool platform with passive mechanical damping, suppressing frequencies above 3 Hz;

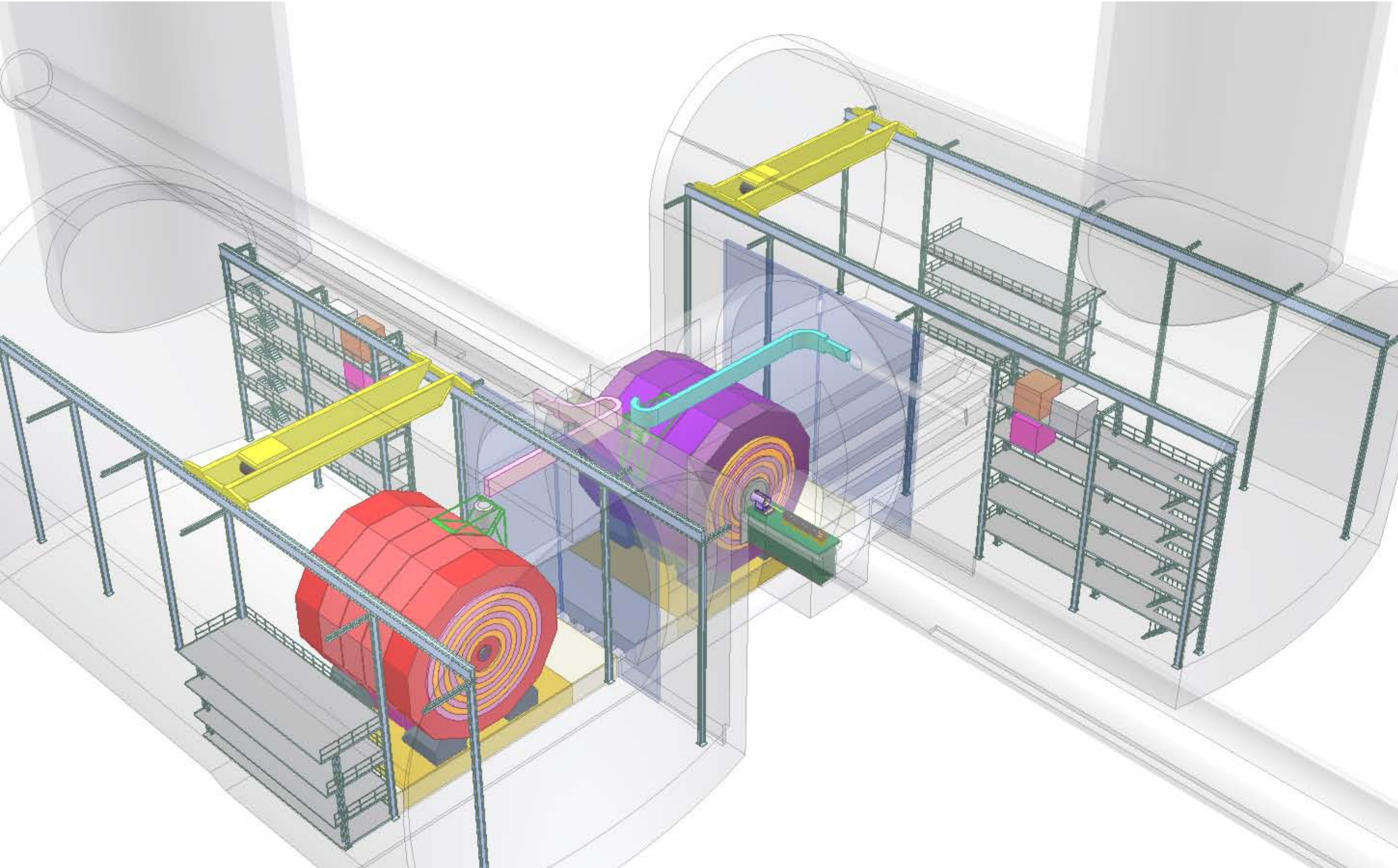
Centre for Metrology and Accreditation
Helsinki, Finland



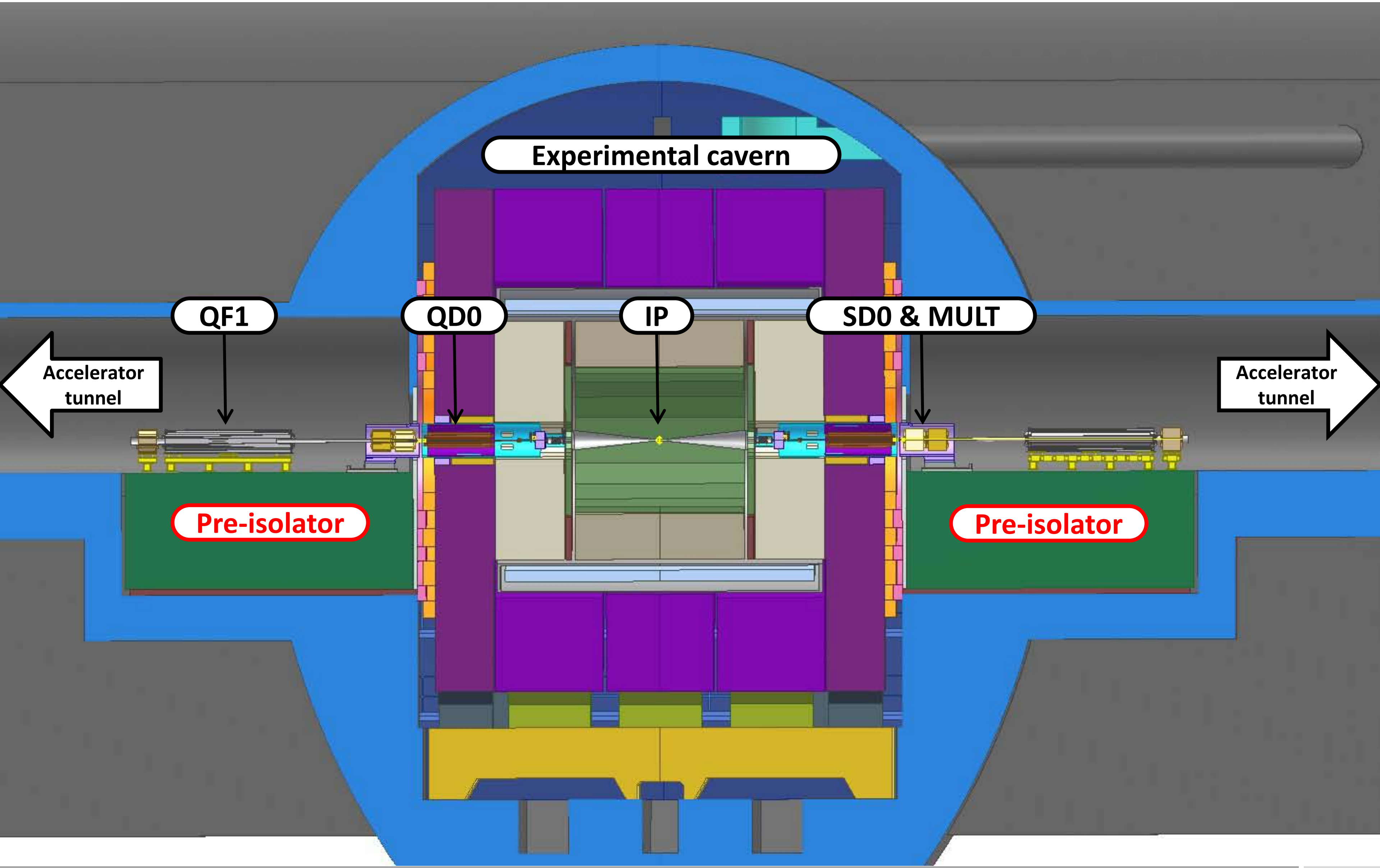
Description:

• 4 concrete pedestals (3x70 ton + 1x140 ton) supported by 0.8 Hz pneumatic vibration isolators;

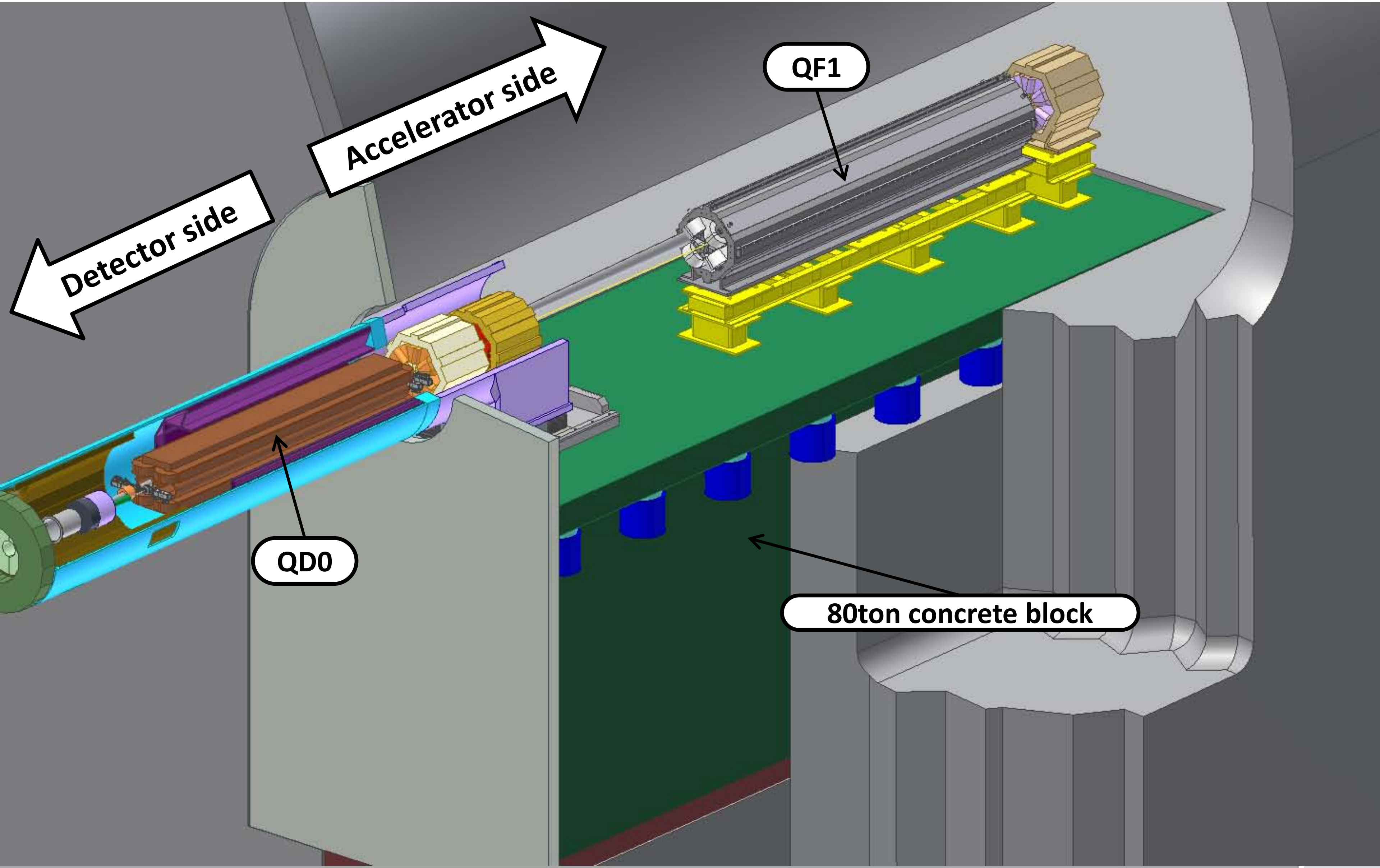
Pre-isolator integration



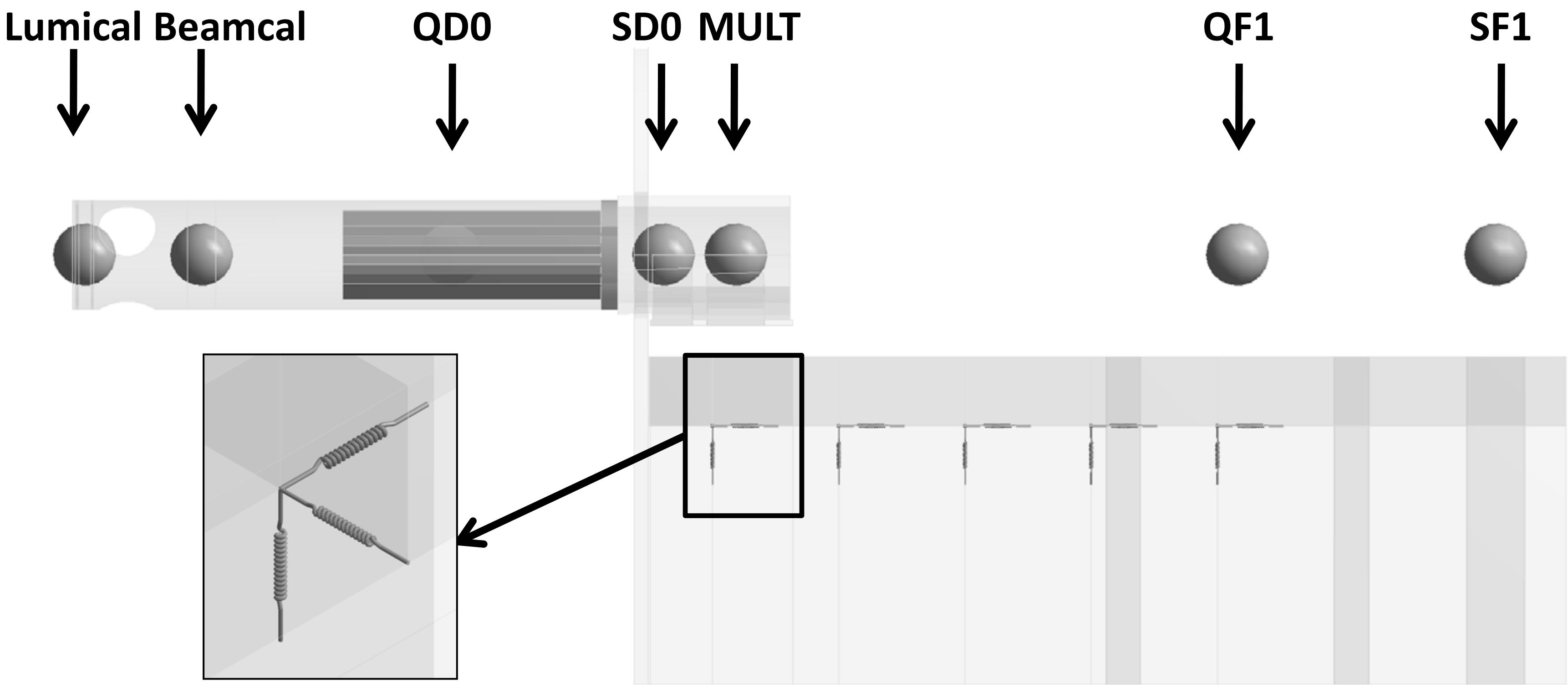
Pre-isolator integration



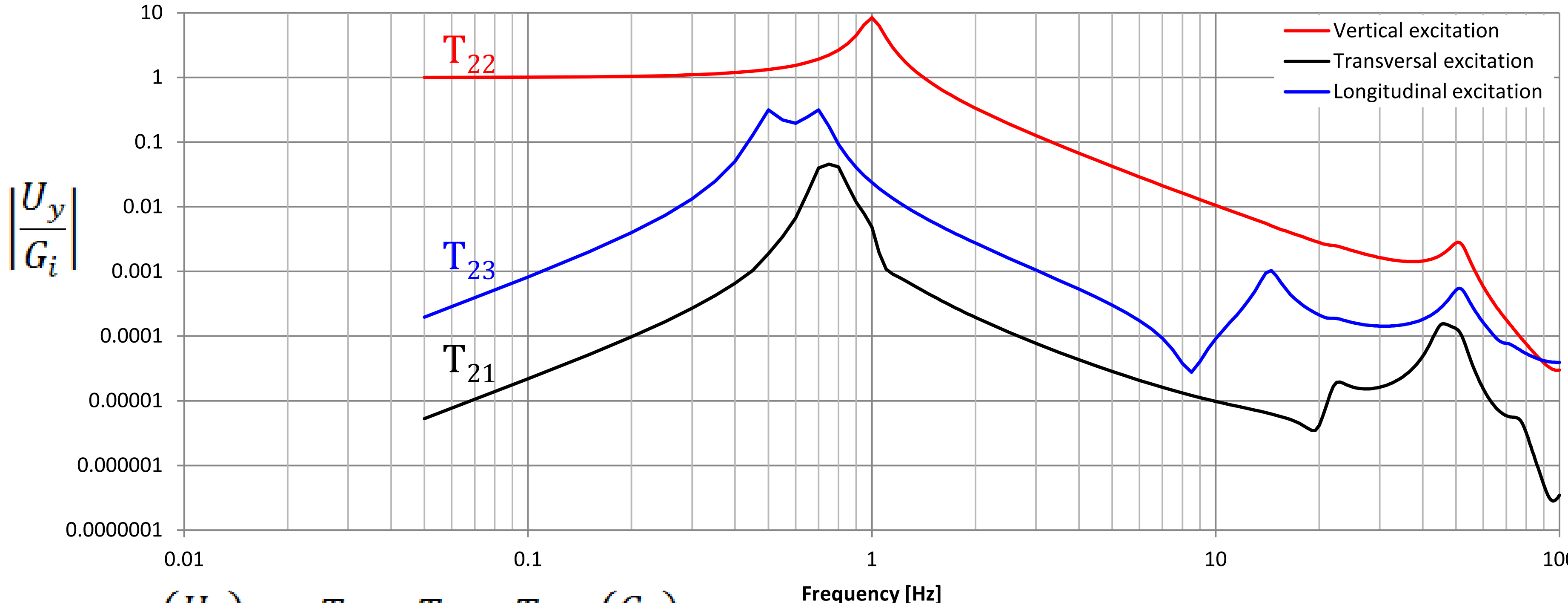
Pre-isolator integration



First FEA simulations



Vertical movement of QD0 vs. ground excitation

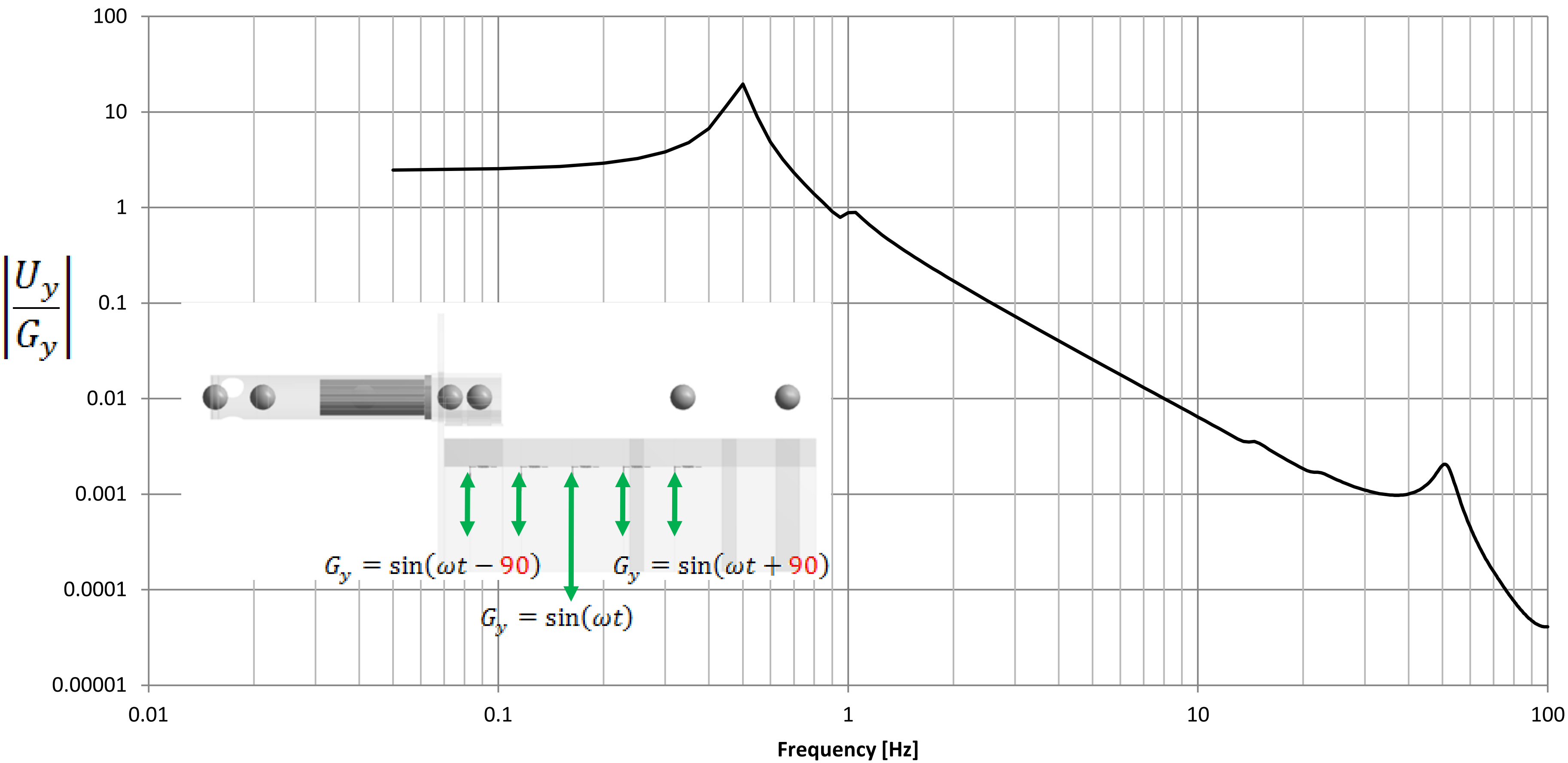


$$\begin{Bmatrix} U_x \\ U_y \\ U_z \end{Bmatrix} = \begin{bmatrix} T_{11} & T_{12} & T_{13} \\ T_{21} & T_{22} & T_{23} \\ T_{31} & T_{32} & T_{33} \end{bmatrix} \begin{Bmatrix} G_x \\ G_y \\ G_z \end{Bmatrix}$$

- The main resonance frequency at 1 Hz allows isolation from ground motion above 1.4 Hz;
- The resonance peak at 50 Hz (support tube) is tunned to match the bunch train frequency;
- The design of the pre-isolator results in a good decoupling between the different directions.

Effect of non-coherent ground motion

(Extreme scenario)



Good performance despite the "lever-arm" effect

Passive isolation test set-up

Validate the results from the finite element model

+

Assess the influence of external perturbations in a noisy environment (workshop floor)

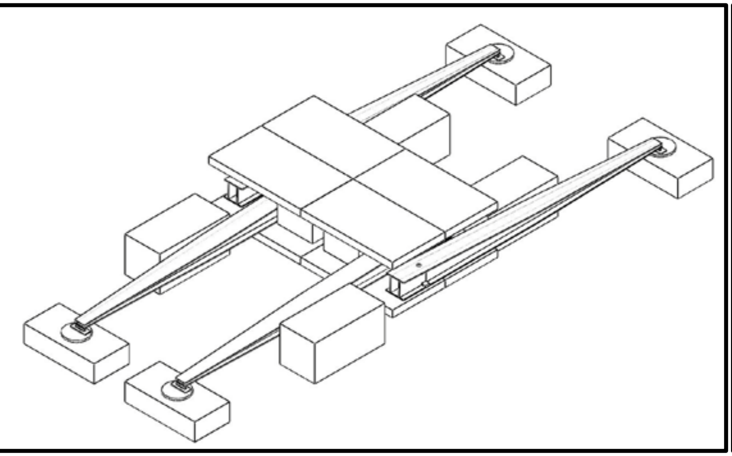
+

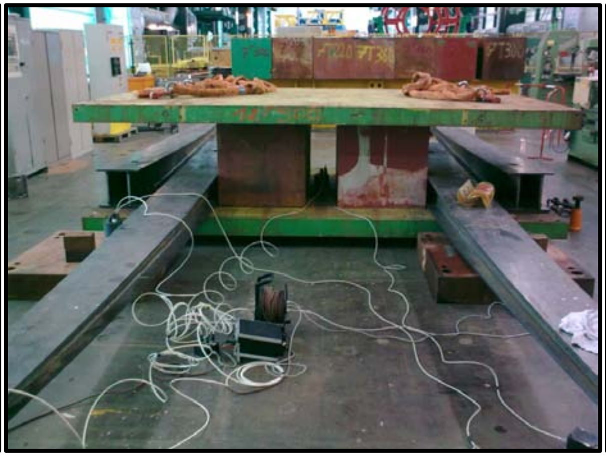
Check for energy loss mechanisms (friction, plastic deformation,...)

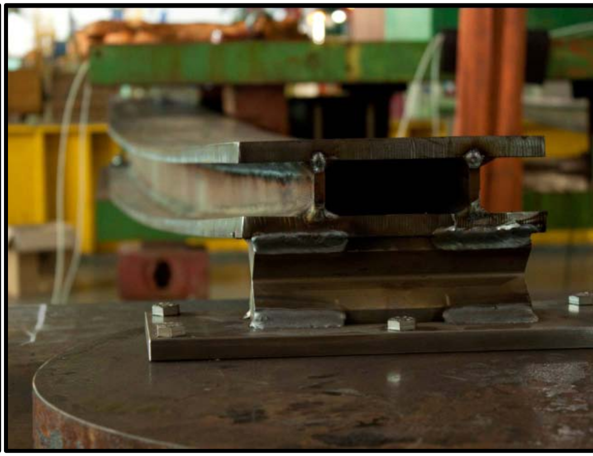
=

Evaluate the performance of a passive system

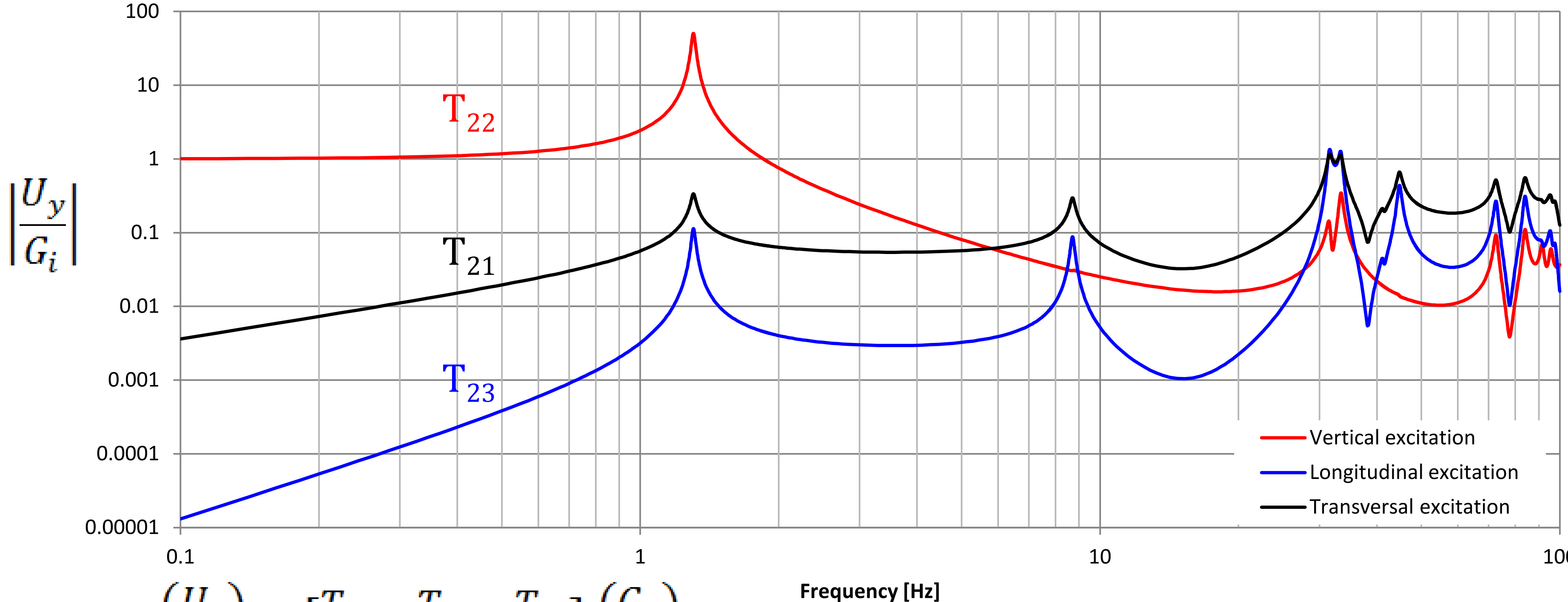
with some of the pre-isolator's characteristics: heavy mass (40 ton) and low natural frequency (1.3 Hz)







Simulated performance



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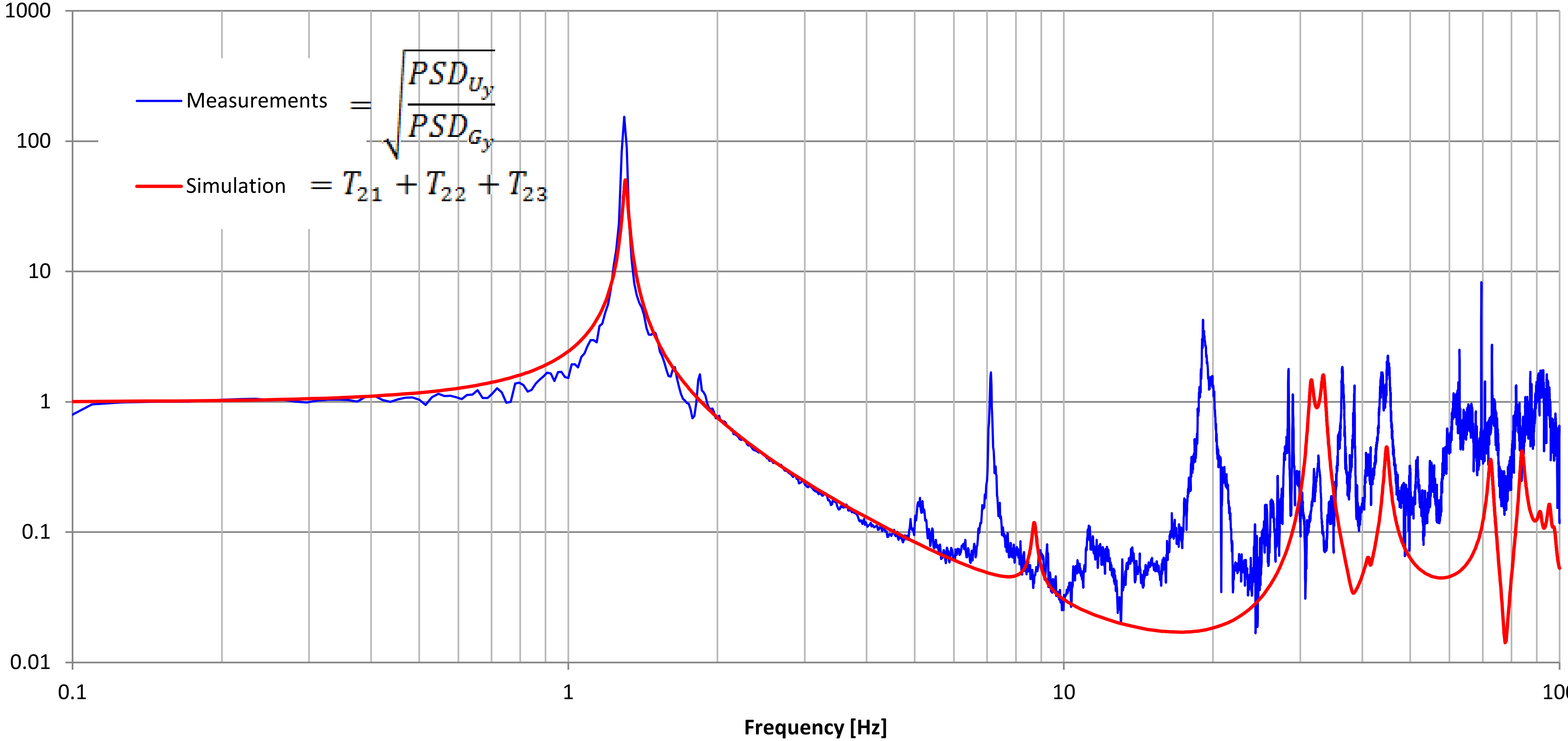
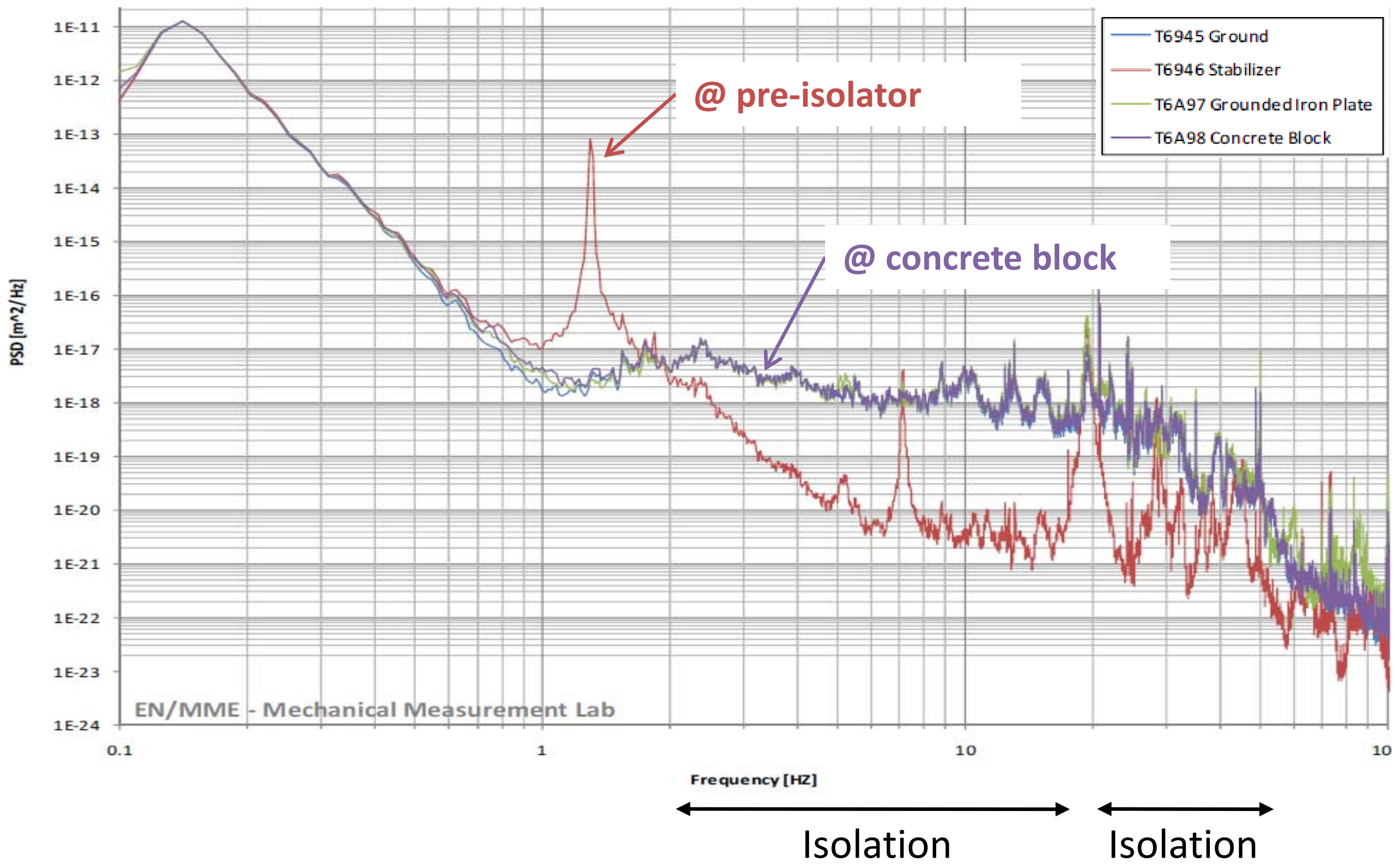
- Design resonance frequency of 1.3 Hz (only slightly above the pre-isolator's one);
- Due to design constraints, higher order eigenfrequencies exist below 100 Hz;
- Decoupling between the different directions does not exist.

Simulation vs. measurements

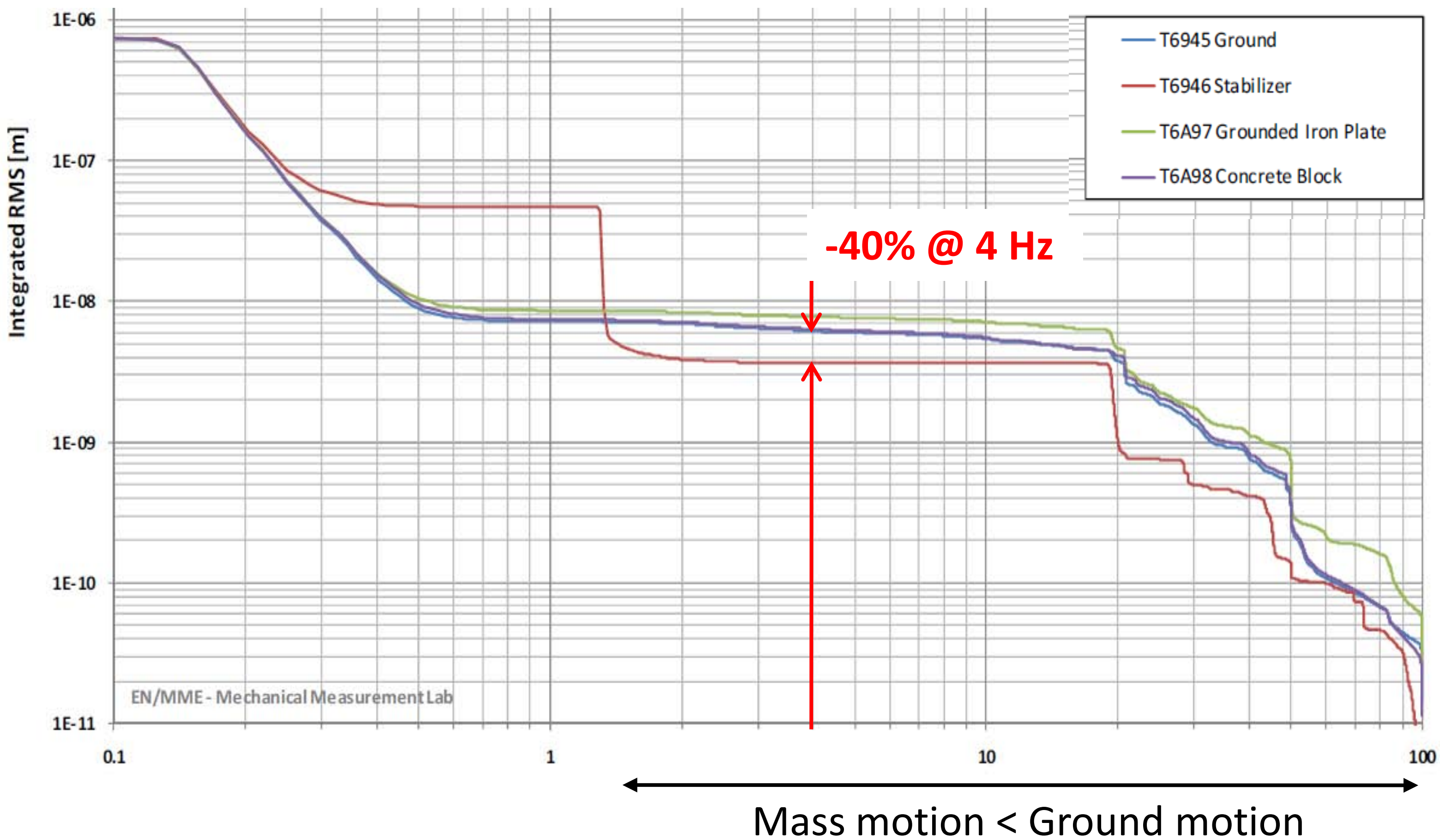


Excellent agreement | Offset | Poor signal-to-noise ratio or higher order phenomenon

Vertical PSD



Integrated vertical r.m.s.



• Despite the higher order eigenfrequencies, a reduction of 40% in the vertical vibration level was still obtained;

• More important, the broad bandwidth of isolation reveals that the system can withstand the action of typical external disturbances (air flow, acoustic pressure, etc.) even in a noisy environment.

Summary (1)

- A pre-isolator is a simple and widely used approach to provide a "stable" ground for the active/beam-based stabilization to work;

- Its low-pass filter nature fits the requirements of stabilizing QD0 above a few (four) Hertz;

- First finite element models have shown the good performance of the proposed design;

- A test set-up confirmed the good match between the measured and simulated data in the low to mid-range frequencies;

- The test set-up also allowed to verify that a massive passive isolation system can perform in a noisy environment;

Summary (2)

- Despite the coupling between the different directions and the high frequency internal modes, the test set-up proved to be robust (the proposed ~110ton system will not suffer from these issues);

- If needed, the low frequency behavior (eigenfrequencies) of the pre-isolator can be addressed (ongoing contacts with industry);

- Integration with other systems has started: J. Snuverink et al., *"Status of Ground Motion Mitigation Techniques for CLIC"*, IPAC11

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Thank you