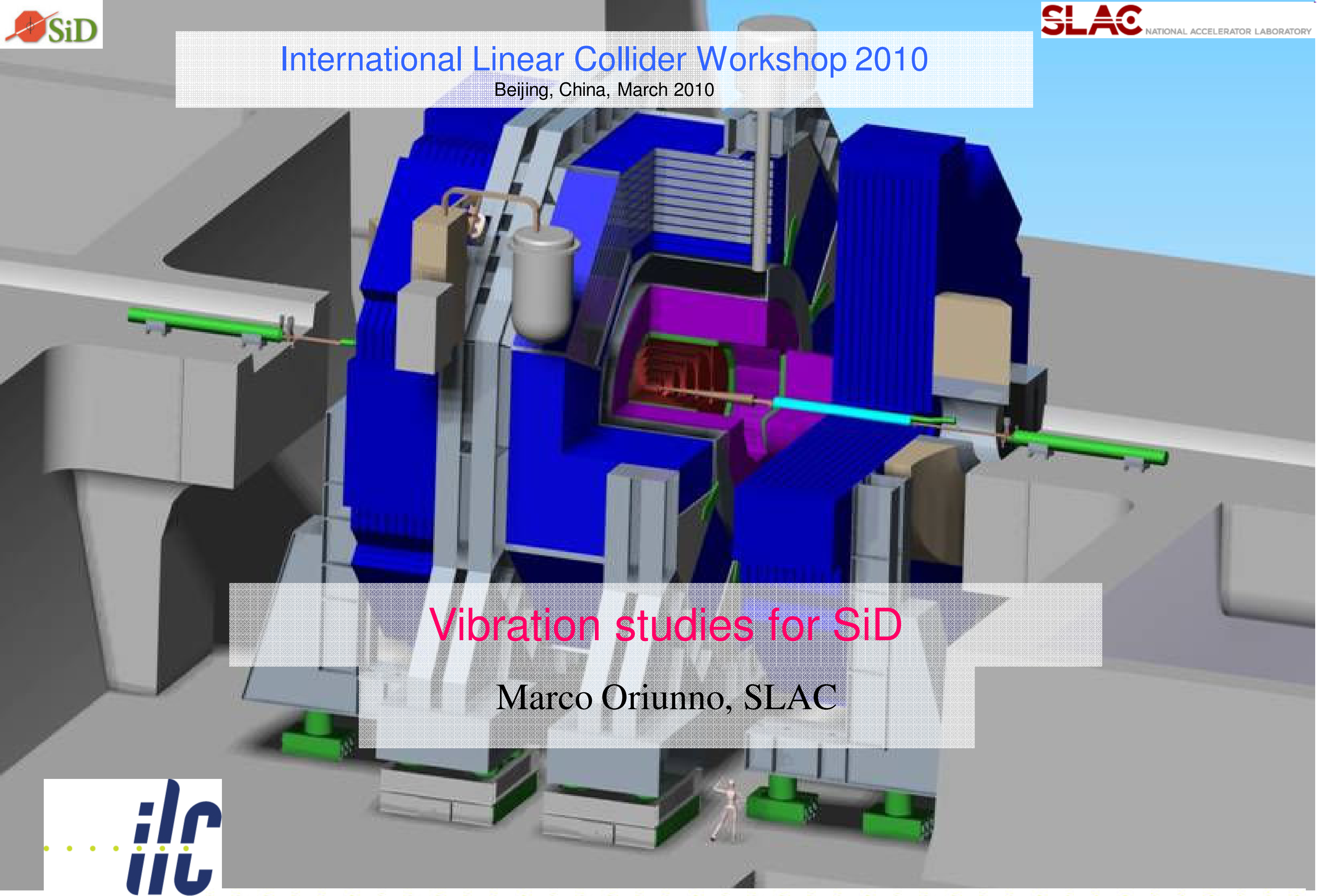
International Linear Collider Workshop 2010

Beijing, China, March 2010



Vibration studies for SiD

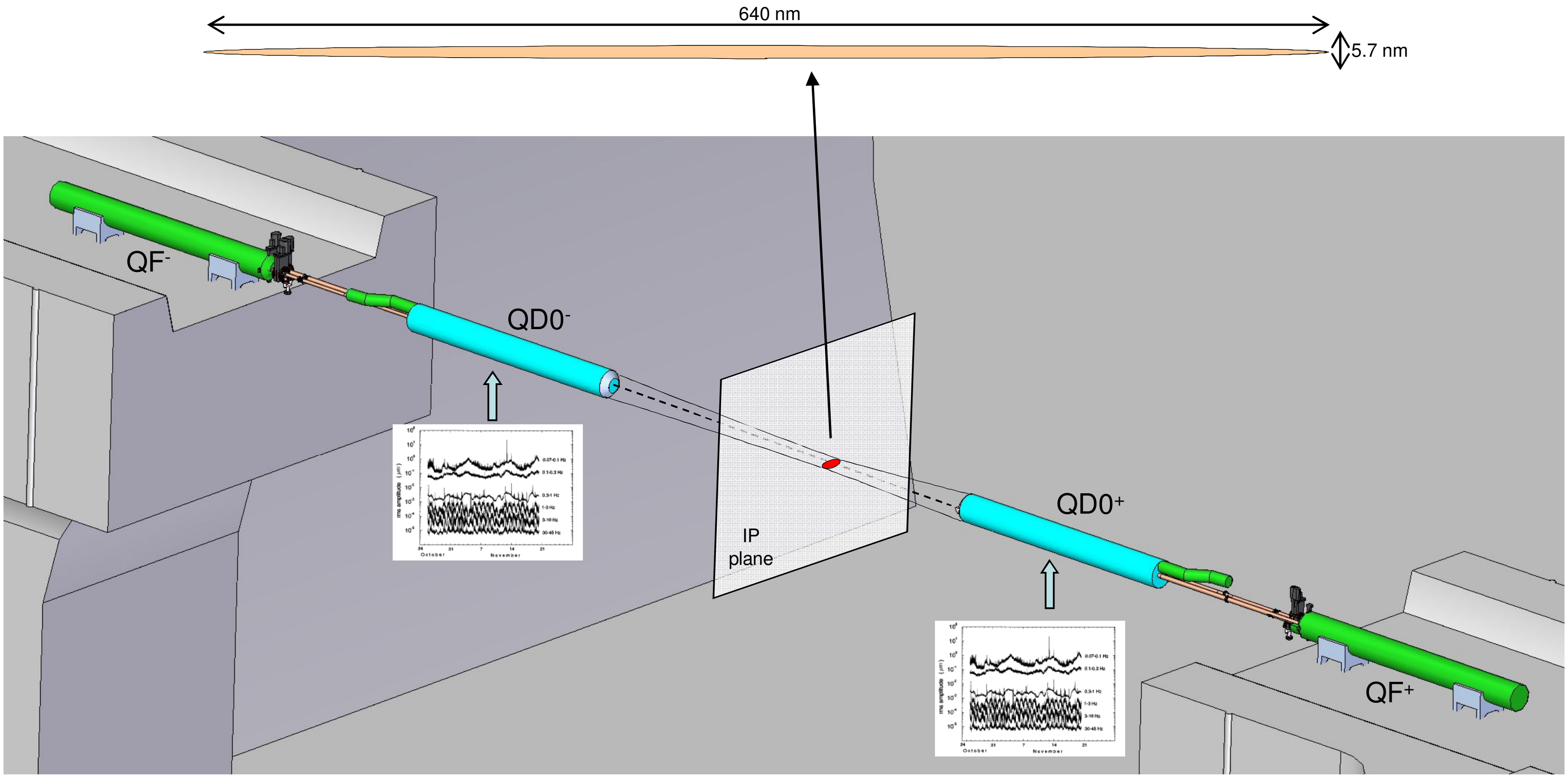
Marco Oriunno, SLAC

Introduction

Sub-nanometric stability of the focusing system is required to maintain the luminosity to within a few percent of the design value.

Ground motion is a source of vibrations which would continuously misaligning the focusing elements.

The design of the support of the QD0 is a fundamental issue



Luminosity feedback systems and stability

Two Luminosity Feedback systems are implemented in ILC :

A 5 Hz to control the orbit in the BDS (low frequency)

A Intra-train system to address ground motion and mechanical disturbances (high frequency~1000 Hz)

The mechanical stability requirements of the QD0 are set by the capture range of the IP fast feedback, as written in the "Functional Requirements" document, ILC-Note-2009-050

" The QD0 mechanical alignment accuracy and stability after beam-based alignment and the QD0 vibration stability requirement are set by the capture range and response characteristics [8] of the inter-bunch feedback system.

- QD0 alignment accuracy: ± 200 nm and 0.1 μrad from a line determined by QF1s, stable over the 200ms time interval between bunch trains
- QD0 vibration stability: Δ(QD0(e+)-QD0(e-)) < 50 nm within 1ms long bunch train "

Ground motions (A.Seryi et al.)

Ground vibrations measurements are available for all the major accelerators sites in form of Power Spectrum Densities. Datasets available at http://vibration.desy.de

Main features :

Separation at ~few Hz between geology and human induced noise (pretty much the separation between the slow and fast luminosity feedback)

Some site are quiet and some are noisy

Motion falls as $1/\omega^4$

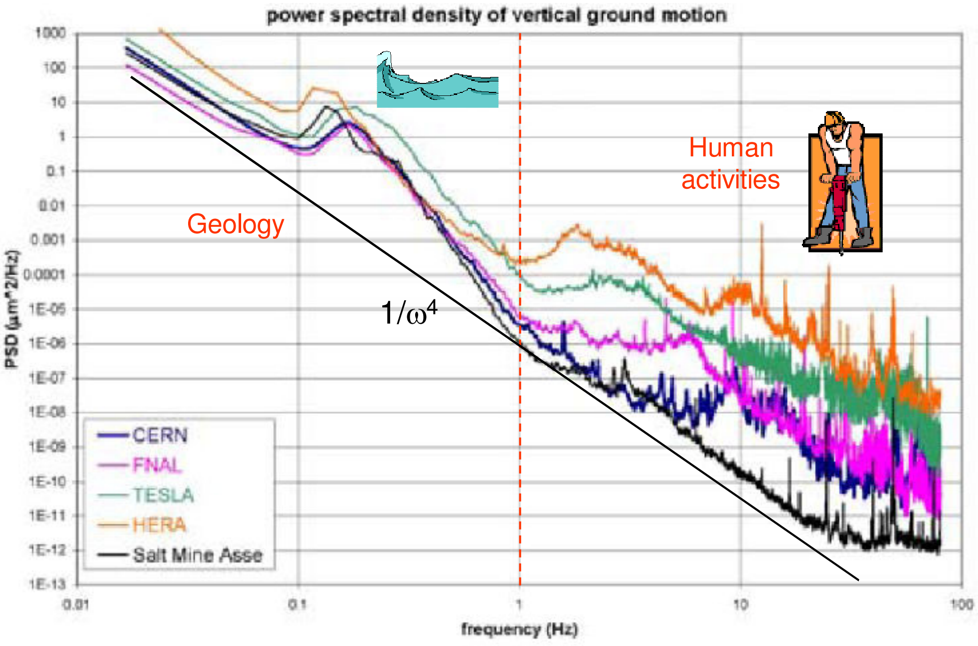
For a given a ground motion time history x(t), the PSD is defined as

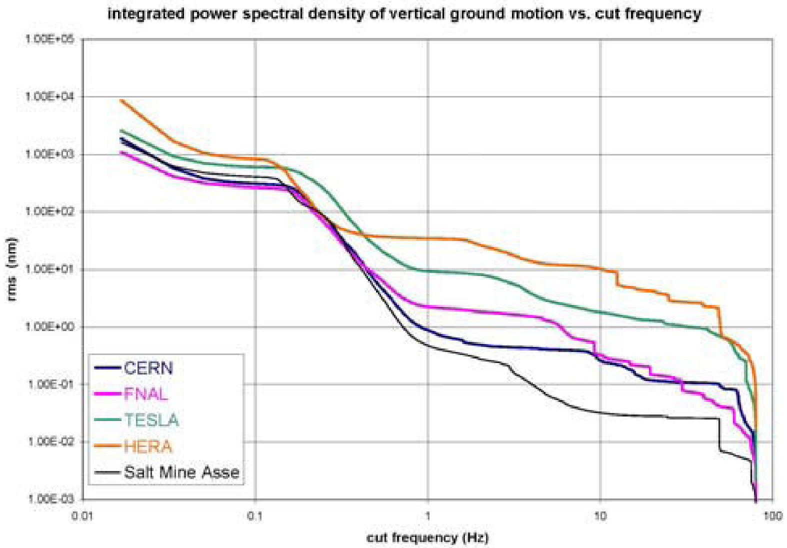
$$P(f)=\lim_{T\to\infty}\frac{1}{T}\left|\int_{-T/2}^{T/2}x(t)e^{-i\omega t}dt\right|^2$$

i.e. *PSD* is the Fourier transform of the *autocorrelation* function R(0) of te signal x(t).

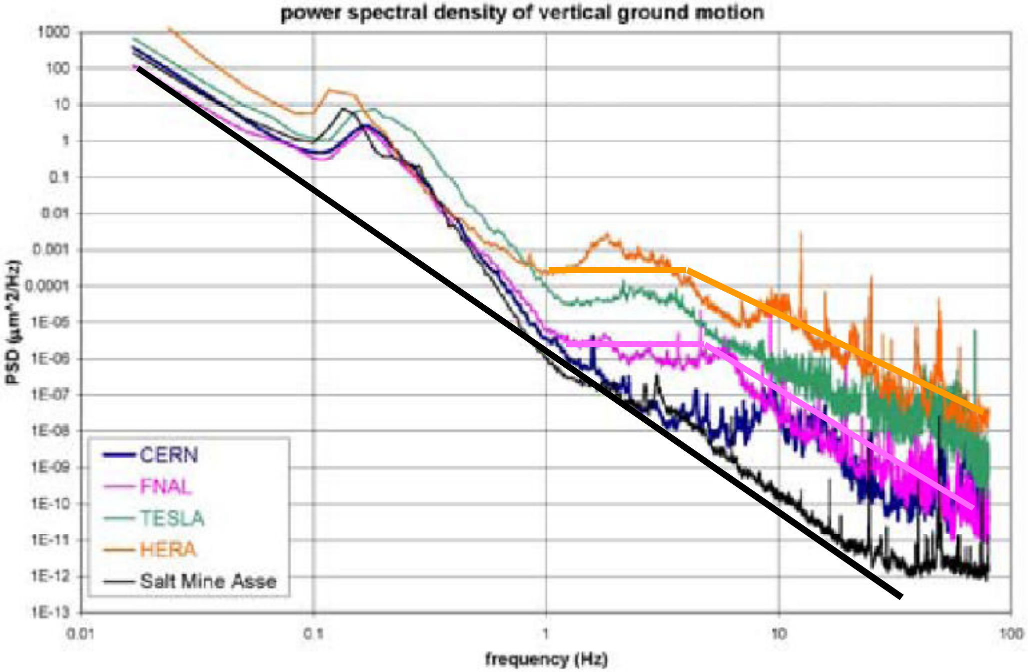
The main property of the PSD is that the variance of x(t) is given by:

$$\sigma^2=\langle x^2\rangle=\int_{f_1}^{f_2}P(f)df$$

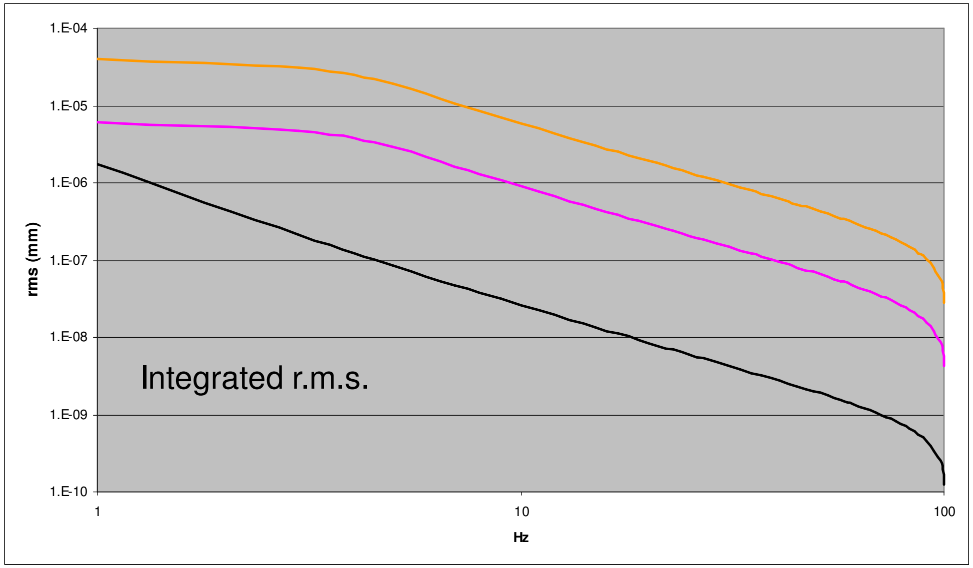




Simplified PSD Models

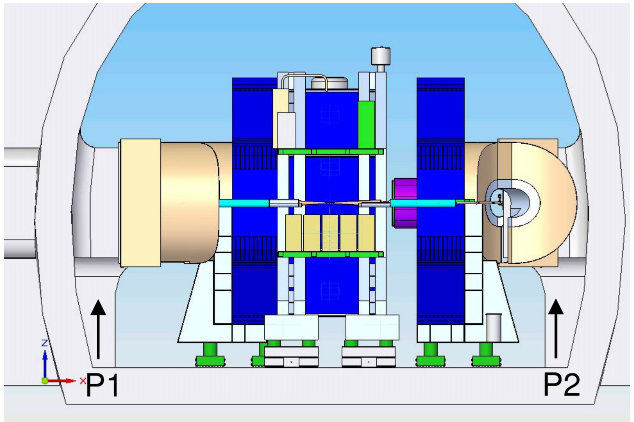


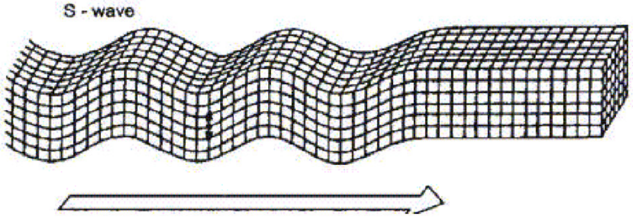
$$P(f) \approx \frac{A}{f^4}$$



$$\sigma^2 = \left\langle x^2 \right\rangle = \int_{f_1}^{f_2} P(f)df$$

Coherence





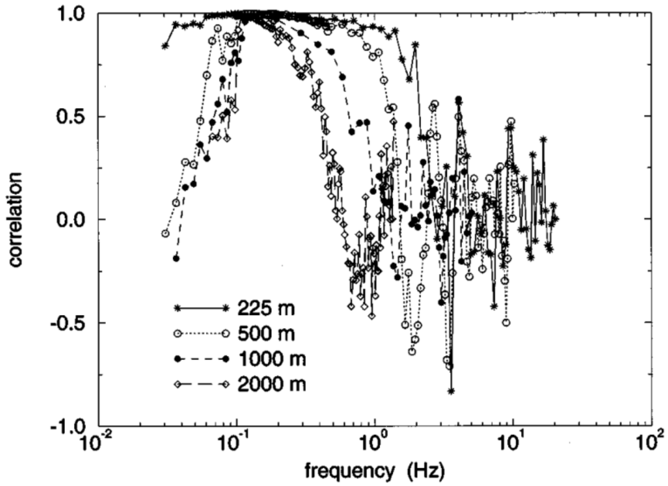


FIG. 3. Correlation spectra of ground motion measured at CERN in the LEP tunnel [7]. The distances between sensors were 225, 500, 1000, and 2000 m.

Coherence : $N_{12}(f) = \dfrac{p_{12}}{\sqrt{p_1 p_2}} = J_0(\omega L/v)$

If P1=P2, then :

Jo = 0th Bessel function

L= distance between points

v = speed of sound in rock, ~3 km/s

$$\rho(\omega,L) = p(\omega)2\{1-\mathrm{Re}[N_{12}(\omega,L)]\}.$$

Relative displacement spectrum

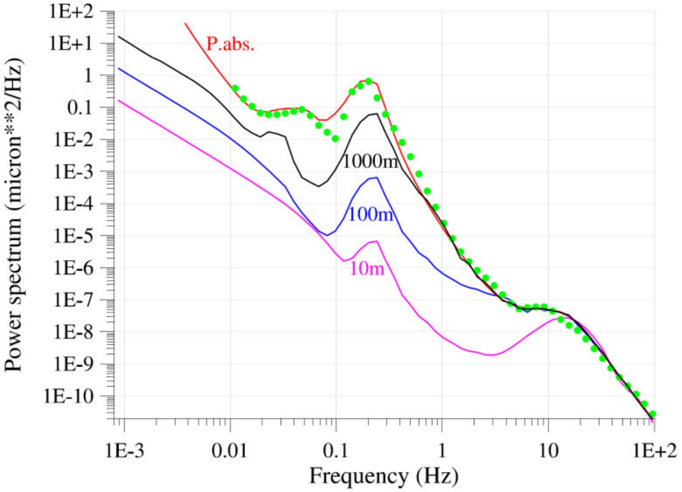


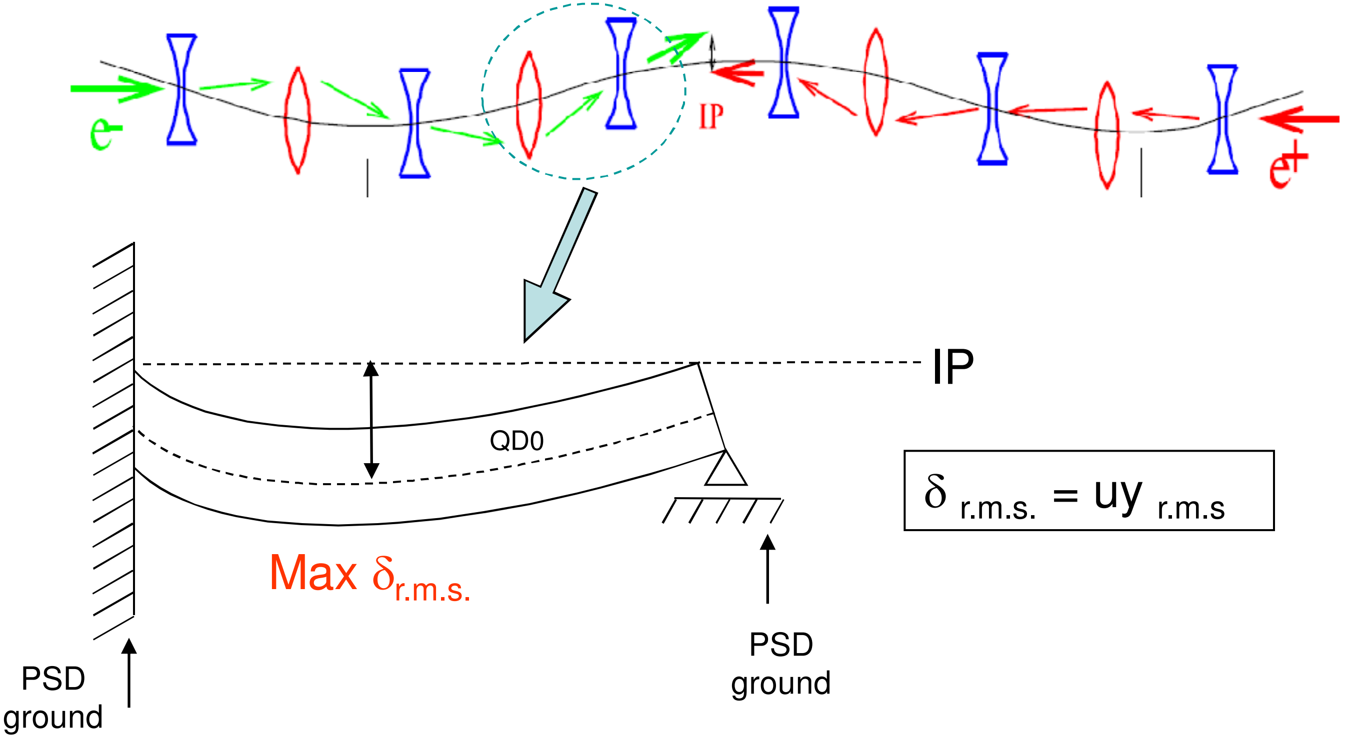
Figure 3: Measured (symbols) and modeling spectra $p(\omega)$ of absolute motion and $p(\omega, L)/2$ of relative motion for the 2 a.m. SLAC site ground motion model.

Random Vibration effects Metric

Ground motion effects are usually accounted as perturbation of the lattice elements through the girders, the magnetic cells assumed point-like (rigid body)

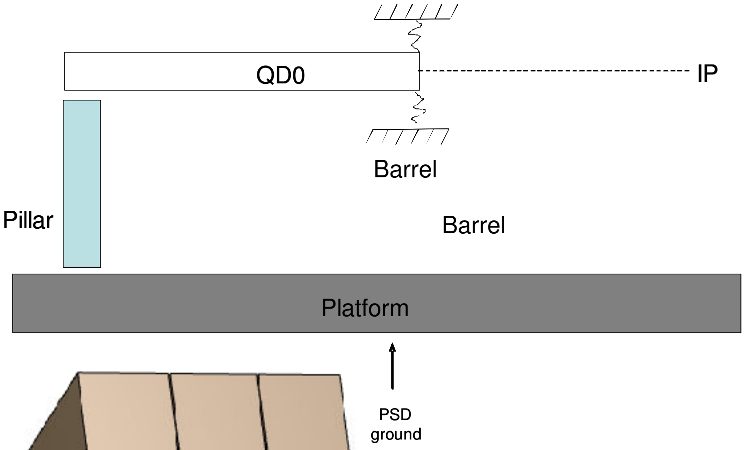
Final Focusing element deforms along the full length under random vibration effects

How define the metric of the net effect of the displacement at the IP ?



$$\delta_{r.m.s.} = uy_{r.m.s}$$

QD0 supports for ILD and SiD



QD0

IP

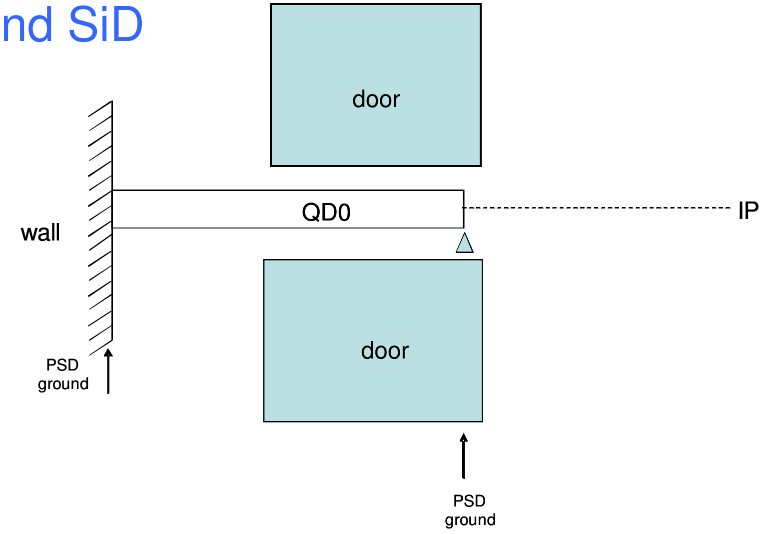
Barrel

Pillar

Barrel

Platform

PSD ground



door

wall

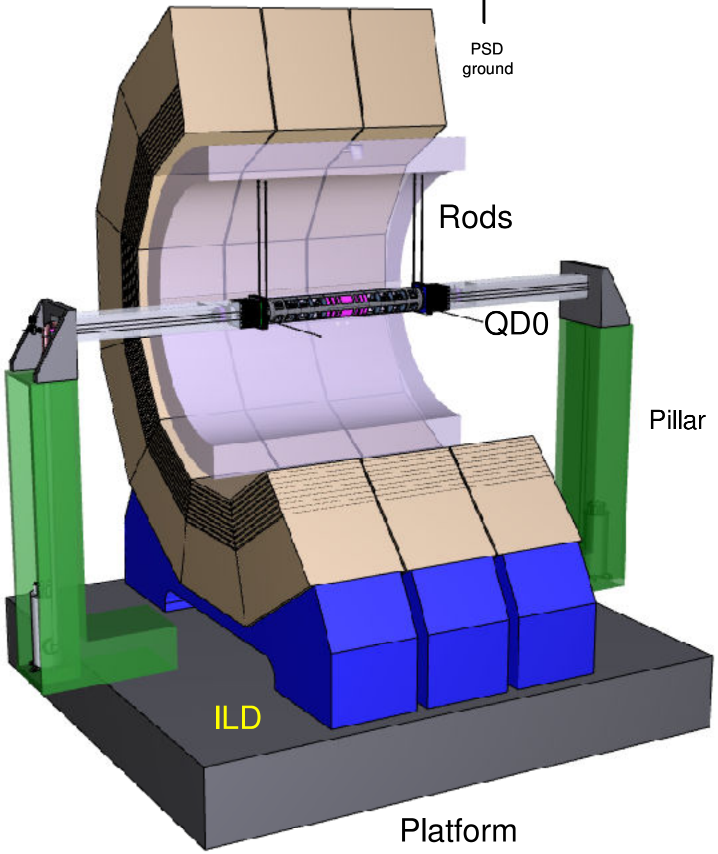
QD0

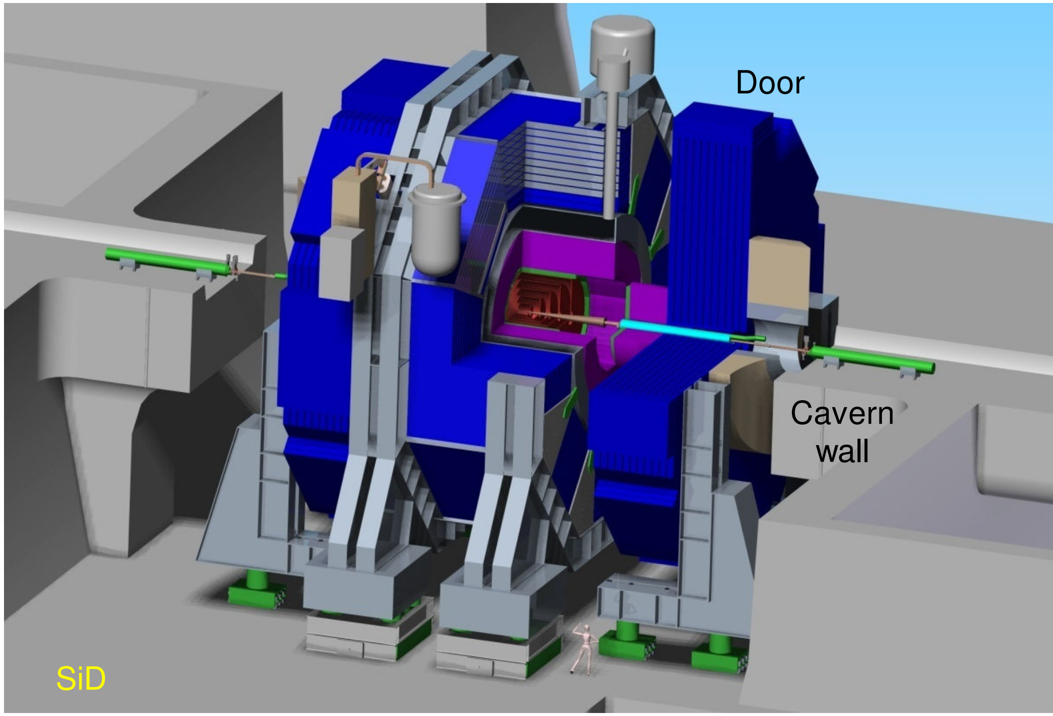
IP

door

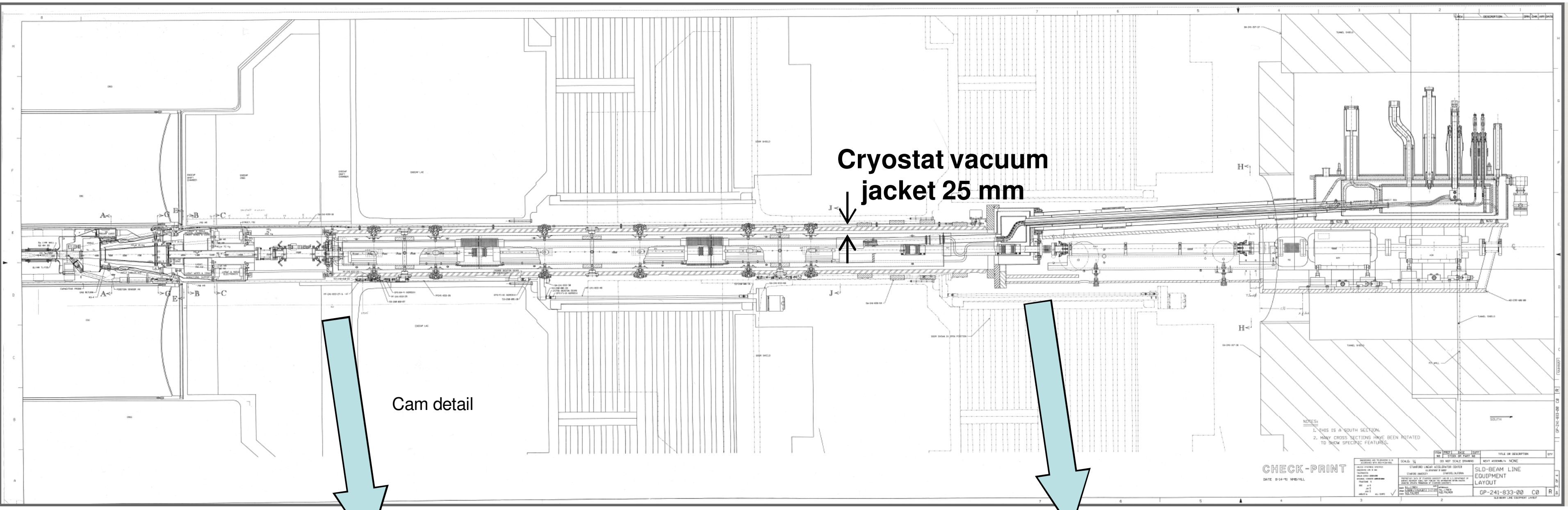
PSD ground

PSD ground



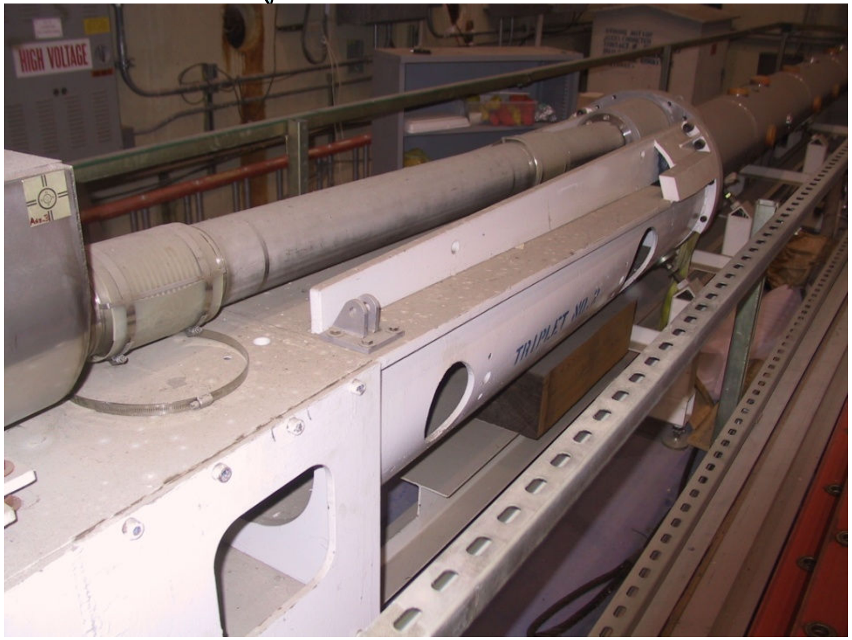


QD0 integration and movement as in SLD

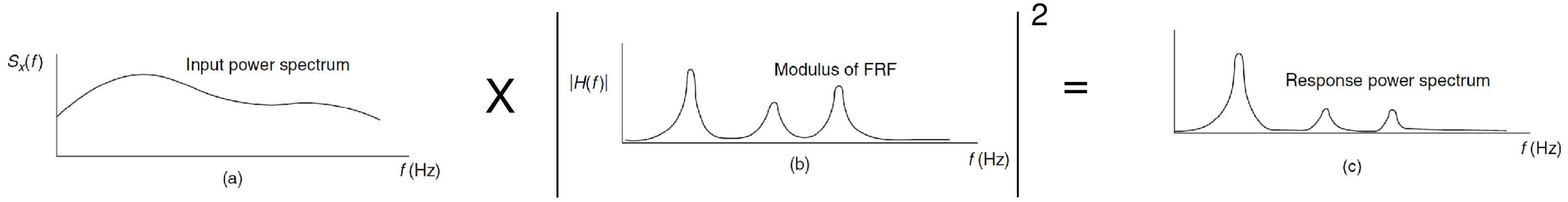


Cryostat vacuum jacket 25 mm

Cam detail



Random vibrations model

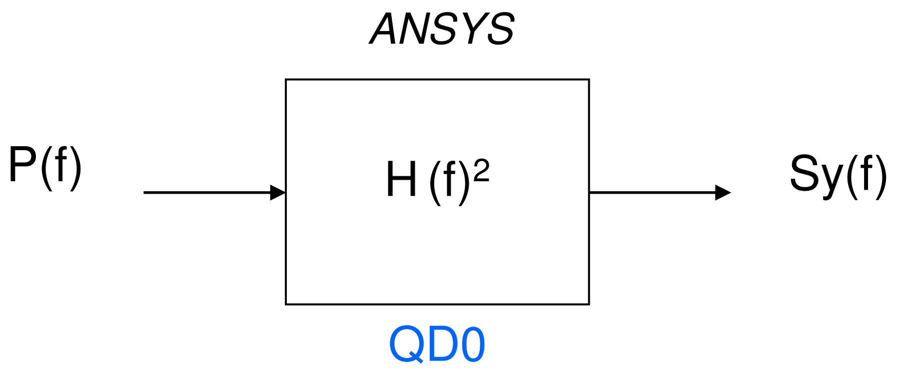


Ground Motion PSD

Frequency Response Function

$$P(f) \times \left|H(f)\right|^2 = Sy(f)$$

The Frequency Response Function for QD0 and SiD is obtained by FEA (e.g. ANSYS)



ANSYS

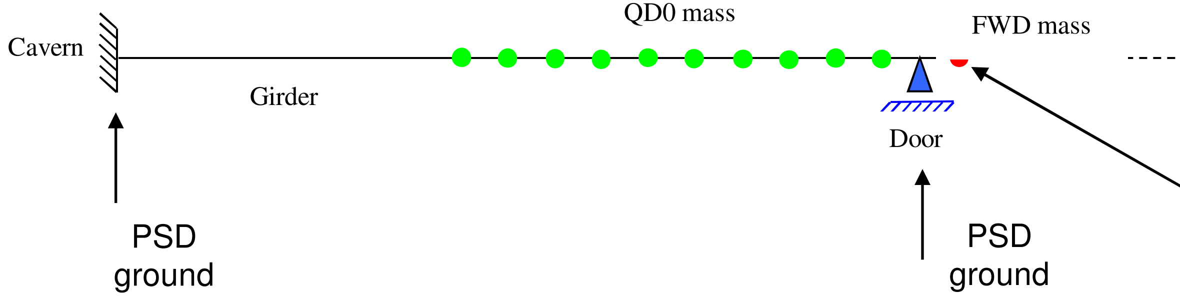
P(f)

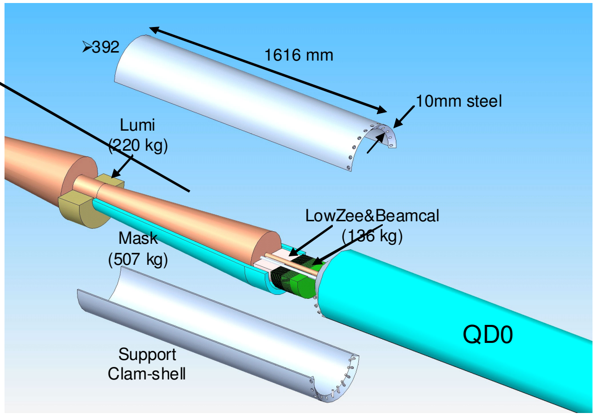
$H(f)^2$

Sy(f)

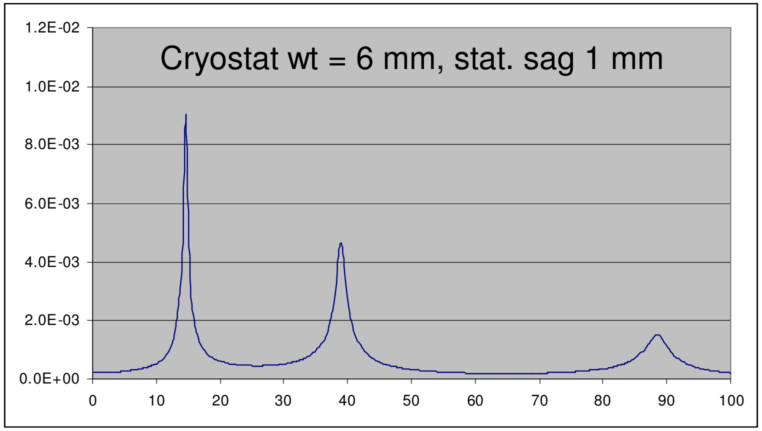
QD0

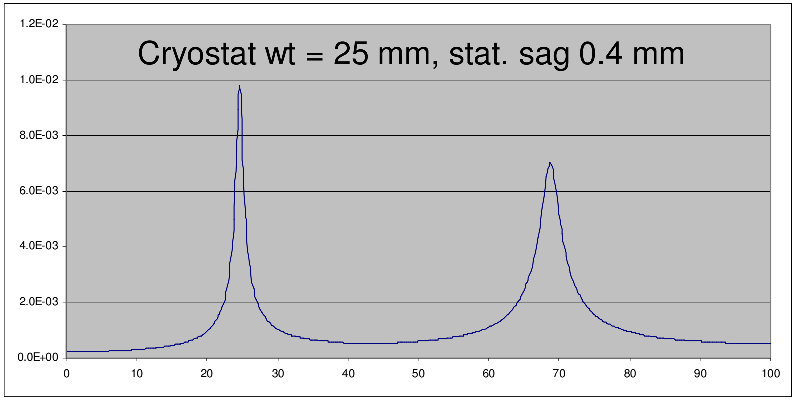
Frequency Response Function of QD0 on the door

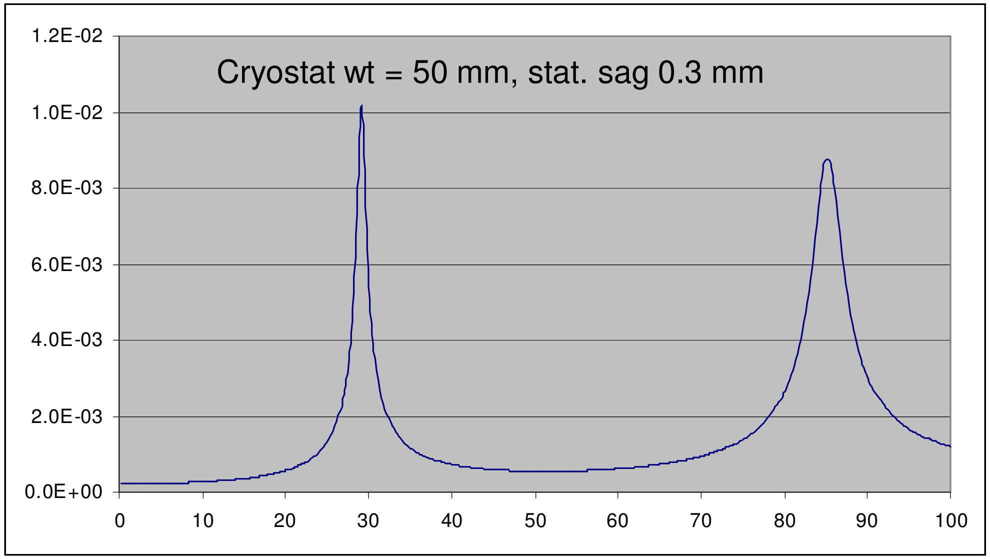




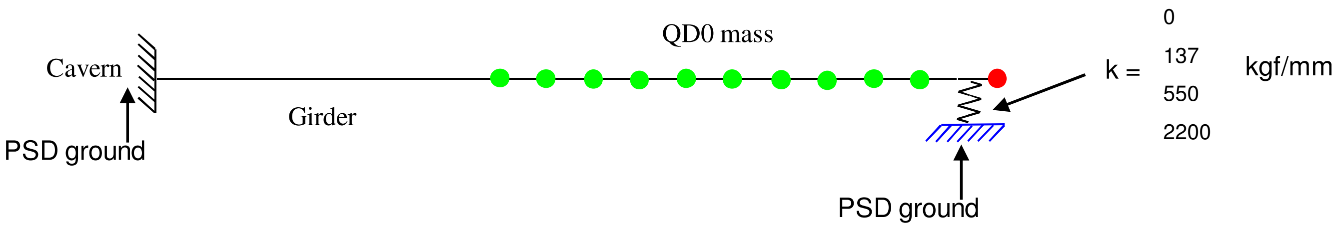
Rot.x Harmonic analysis response for two different cryostat wall thickness: t=6 mm (ILC Nominal), t=25 (SLD), t=50 mm

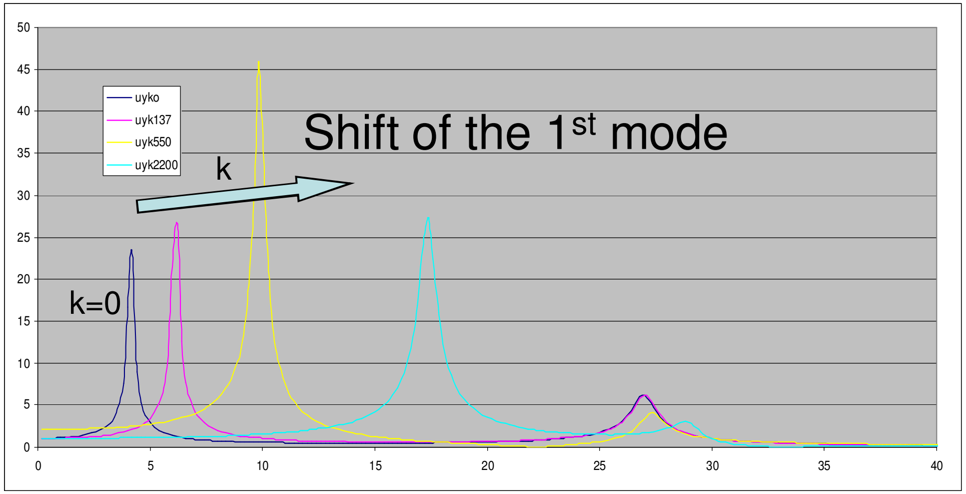


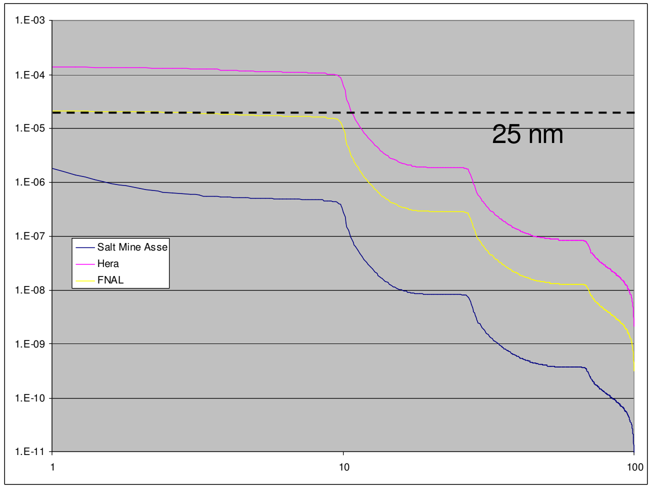


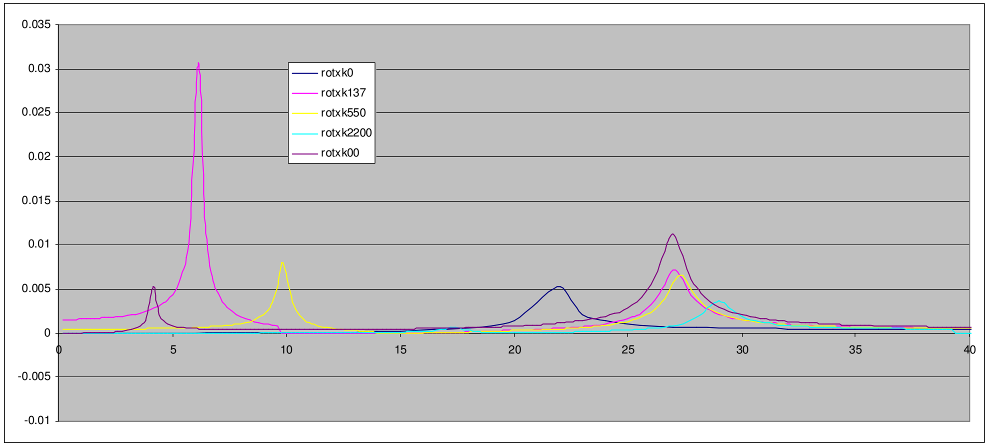


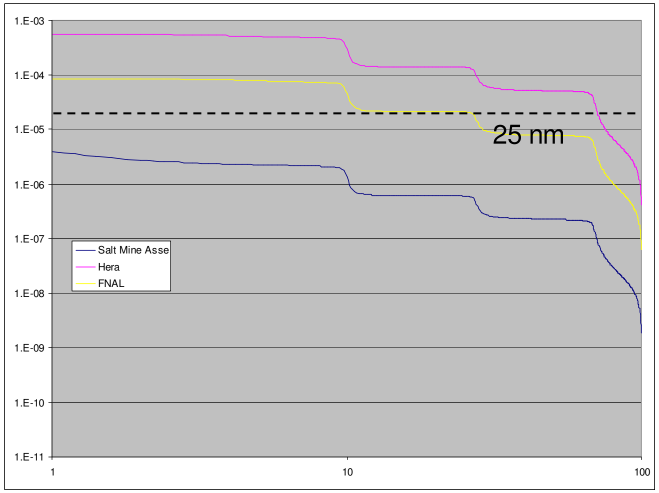
QDO cantilevered + spring suspension from the barrel



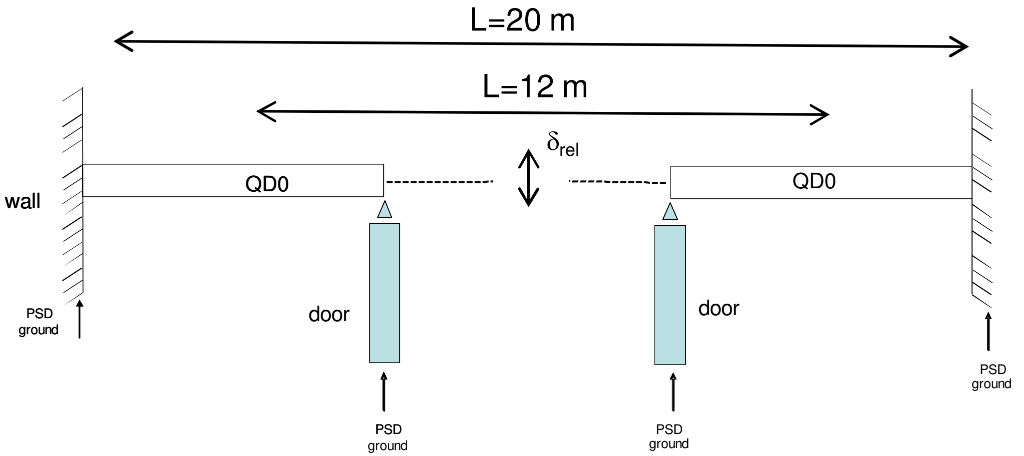




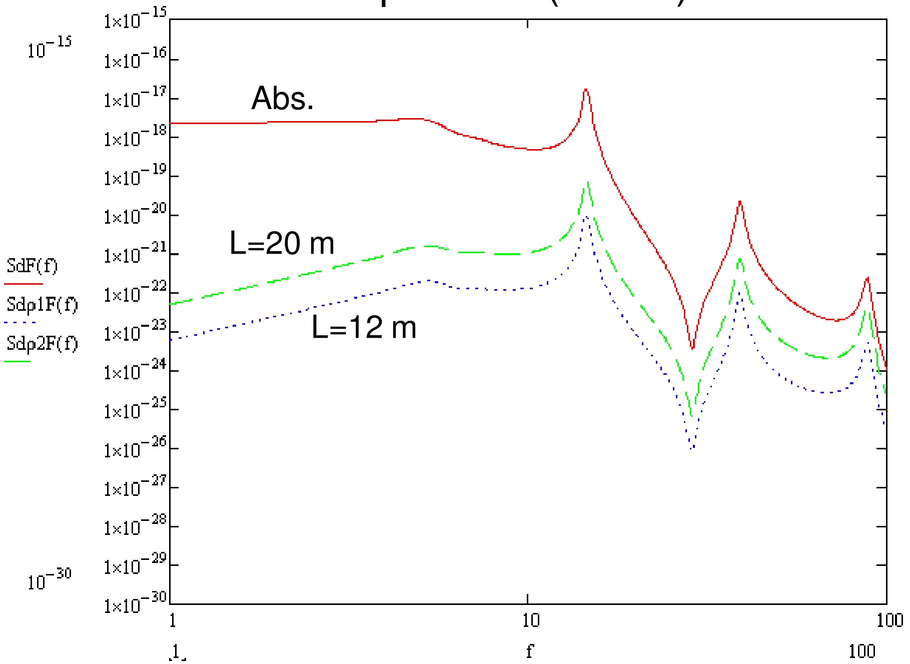




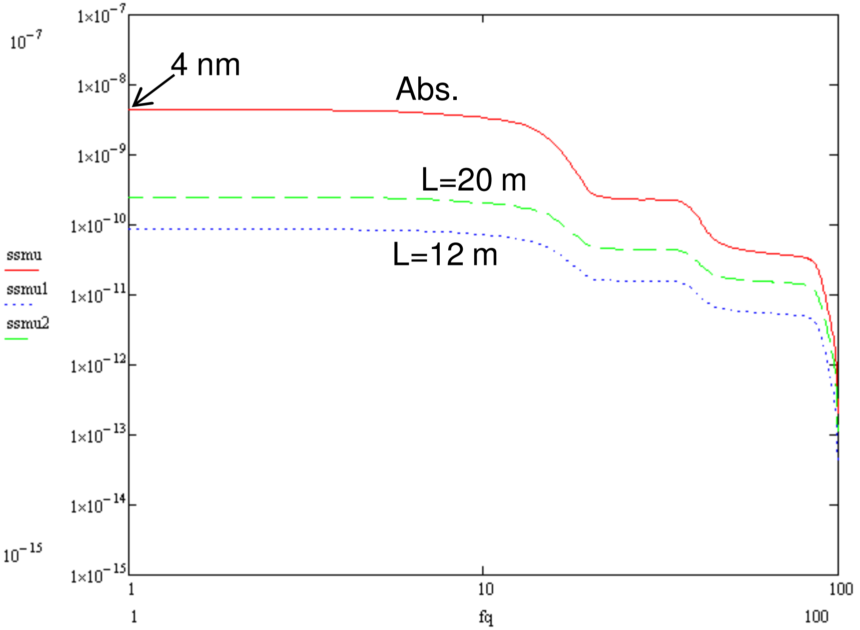
Ends supported



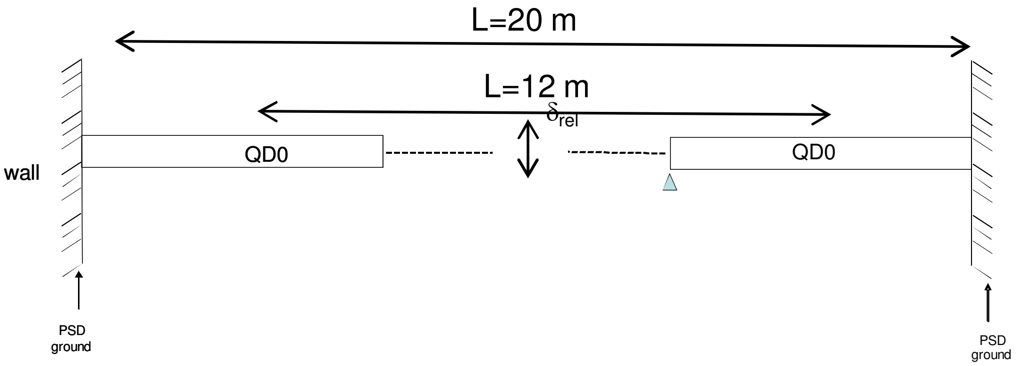
Power Spectrum (m^2/Hz)



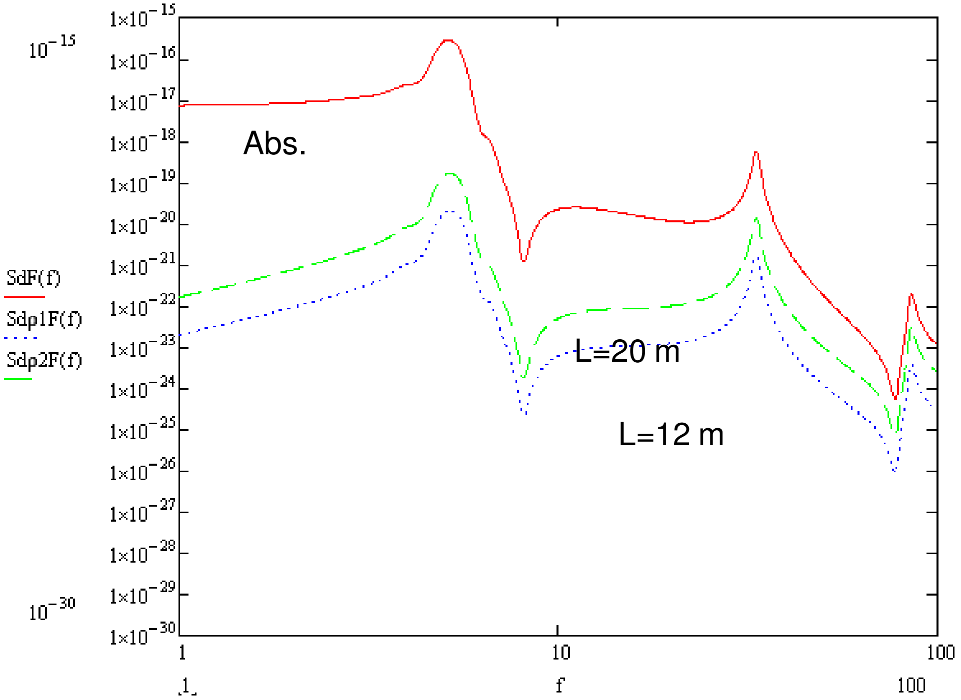
Relative Displacement r.m.s (meters)



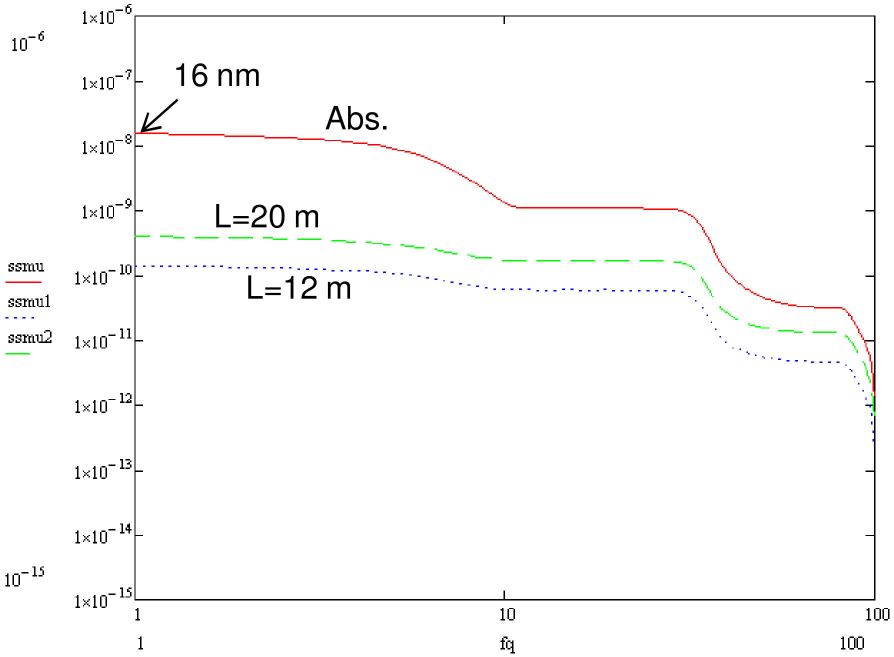
Cantilevered



Power Spectrum (m²/Hz)

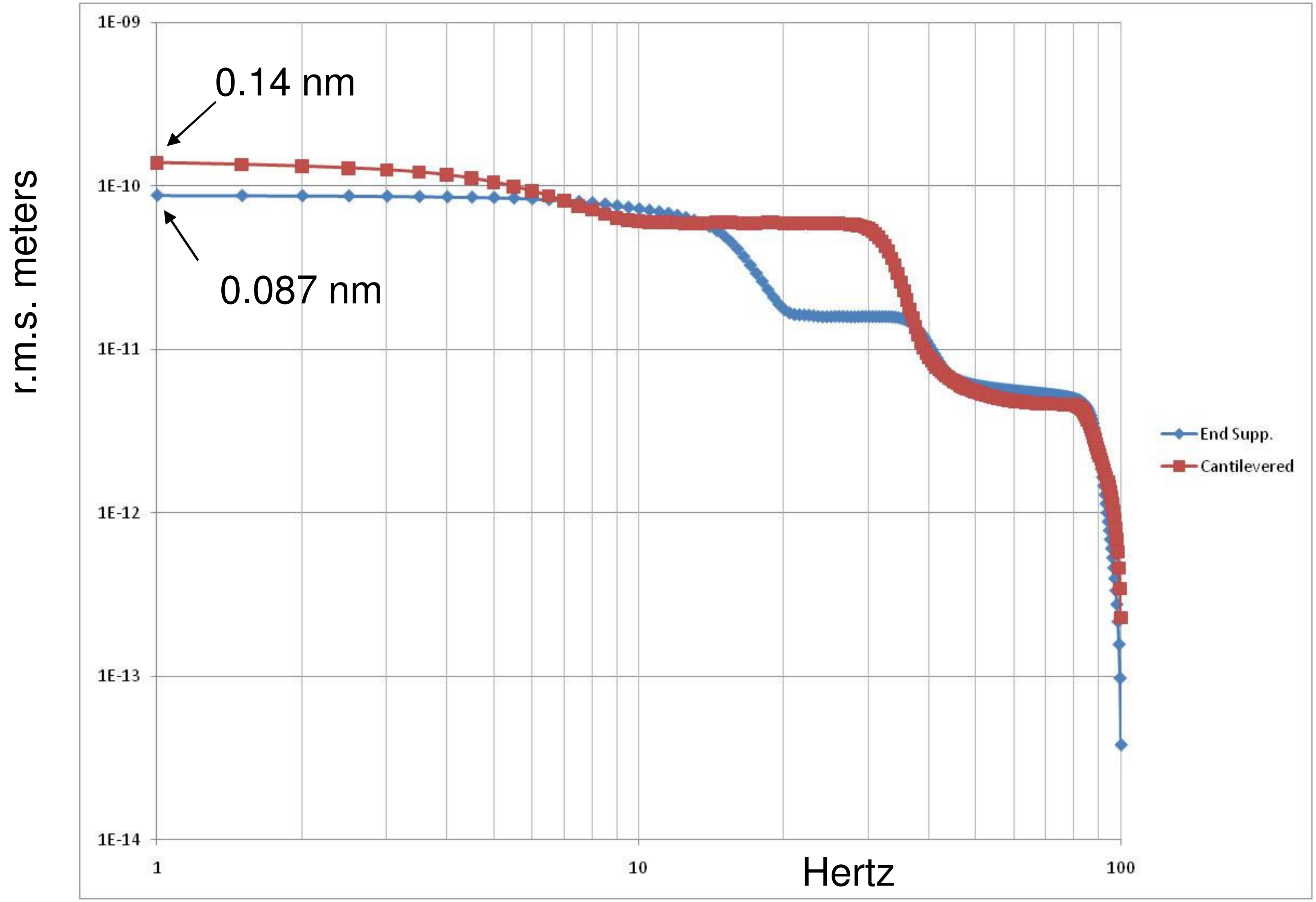


Relative Displacement r.m.s (meters)



Relative displacement (r.m.s.) meters

End Supports vs. Cantilevered QD0



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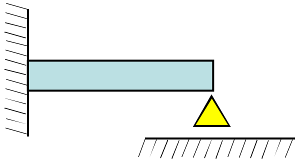
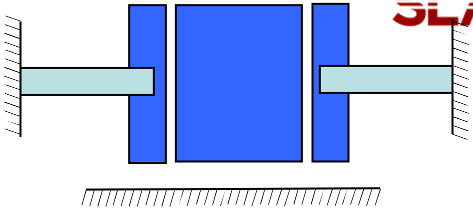
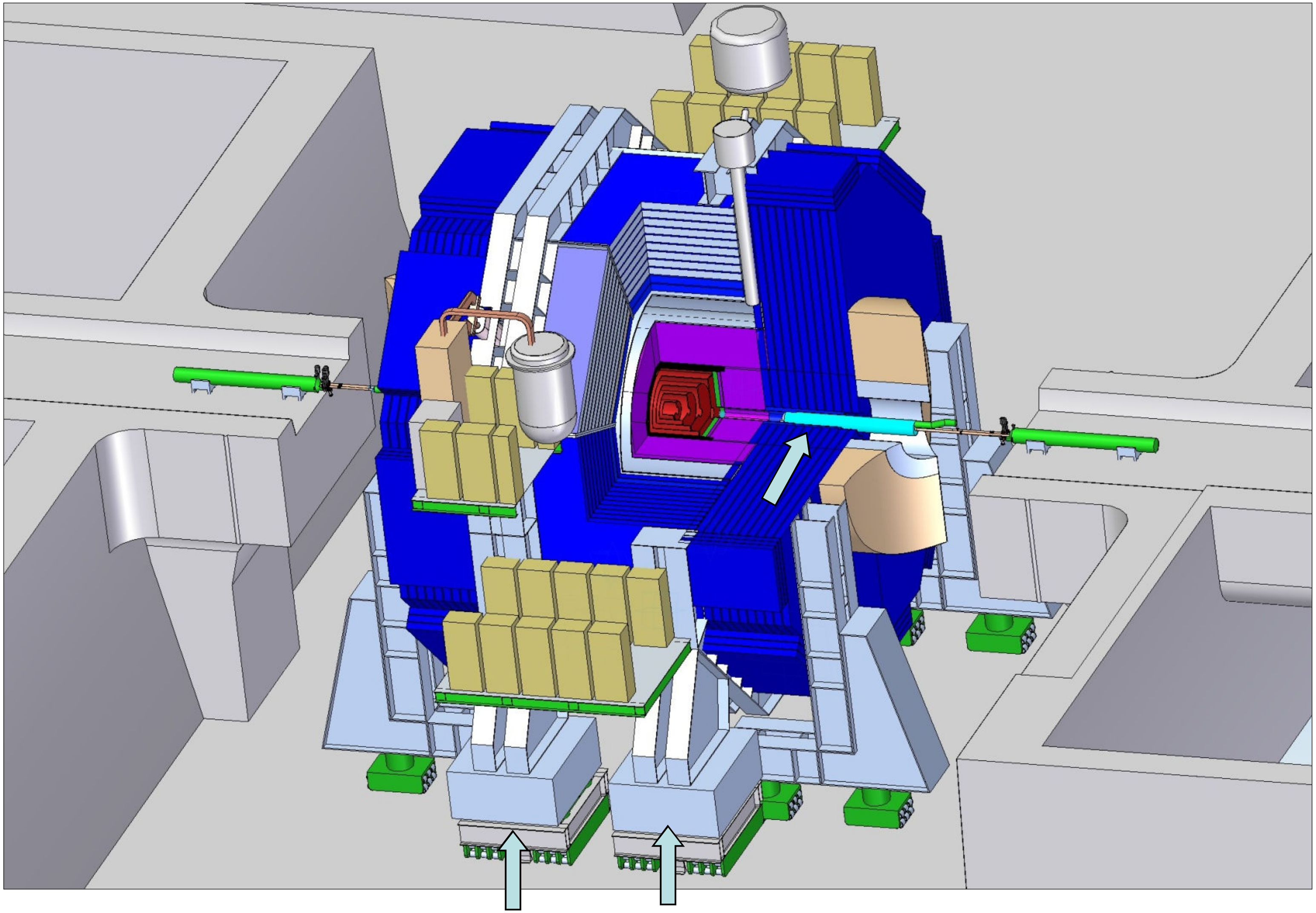


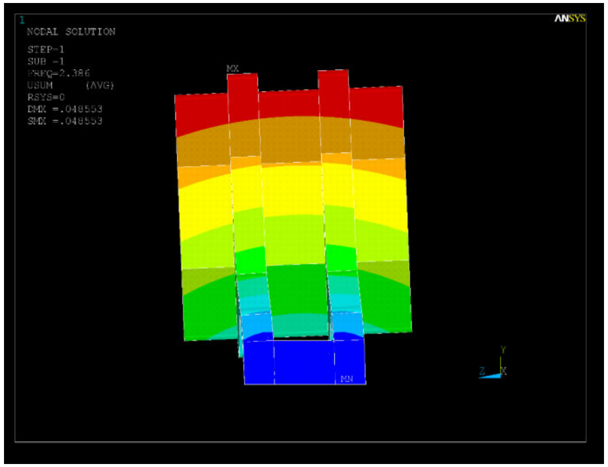
…….to this



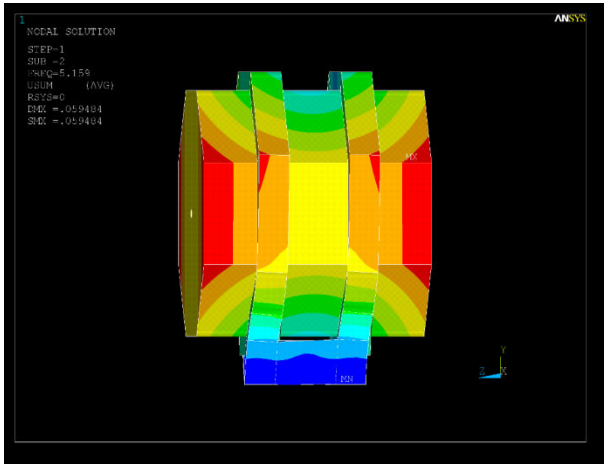


Ground motion through the feet

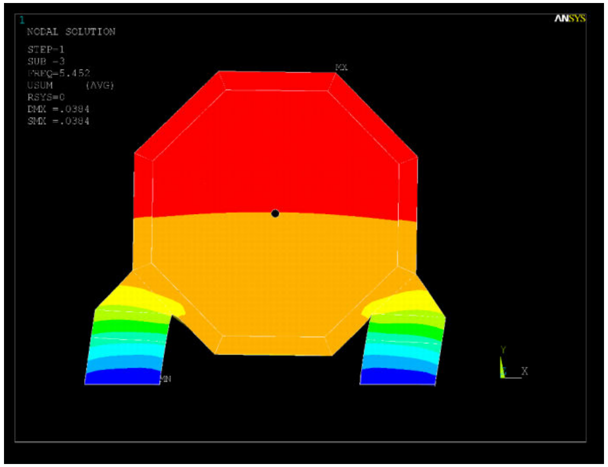
SiD Free Vibration Mode



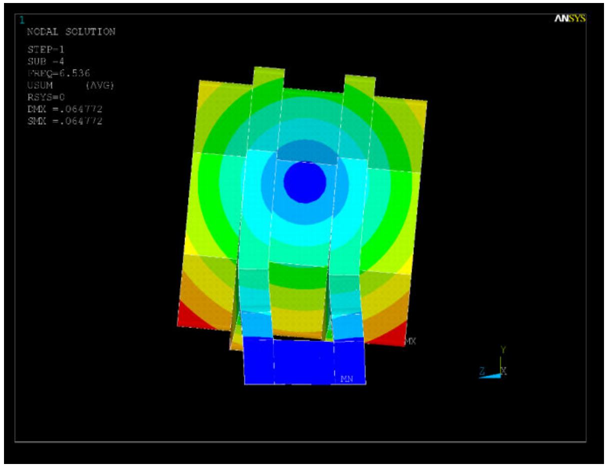
1st Mode, 2.38 Hz



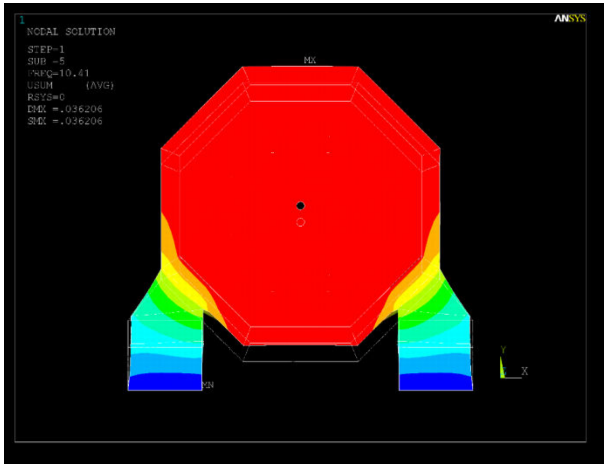
2nd Mode, 5.15 Hz



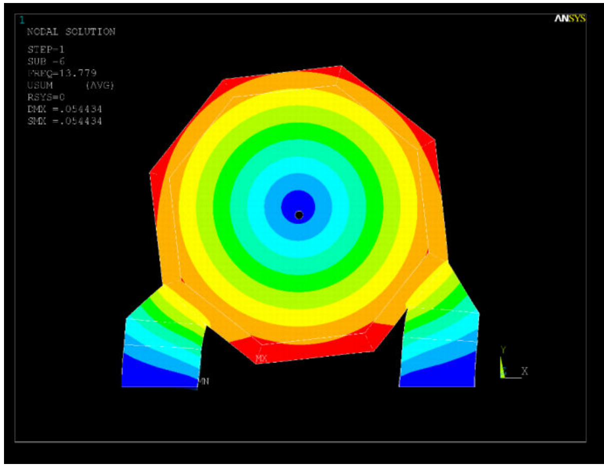
3rd Mode, 5.45 Hz



4th Mode, 6.53 Hz



5th Mode, 10.42 Hz

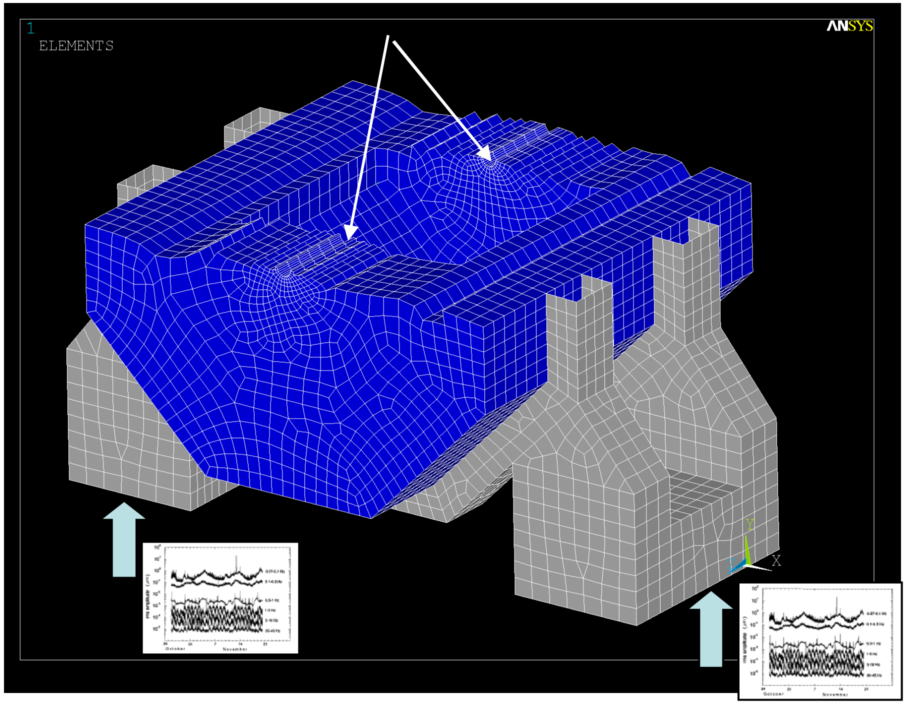


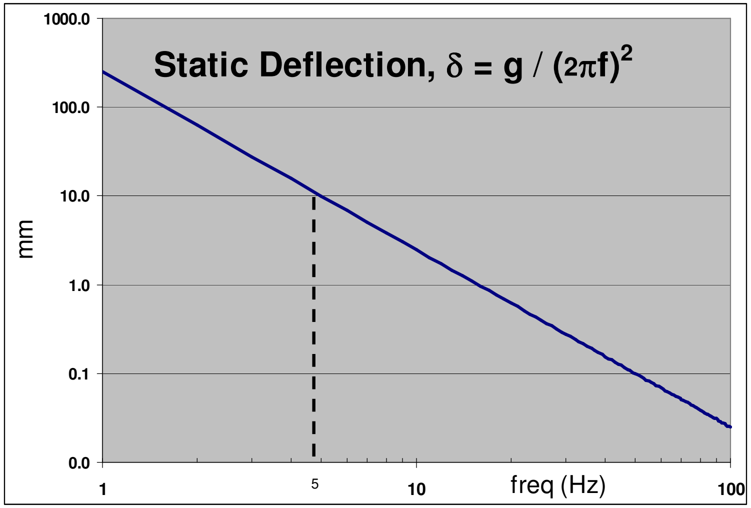
6th Mode, 13.7 Hz

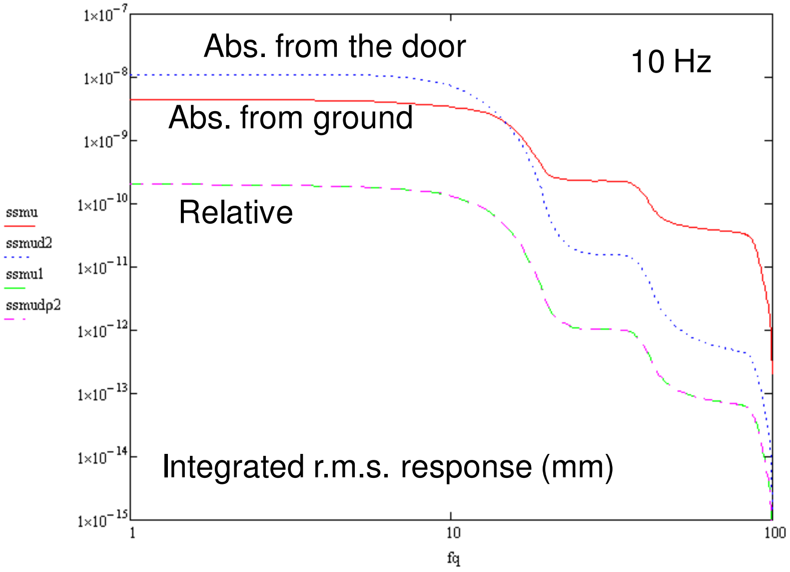
Vertical motion

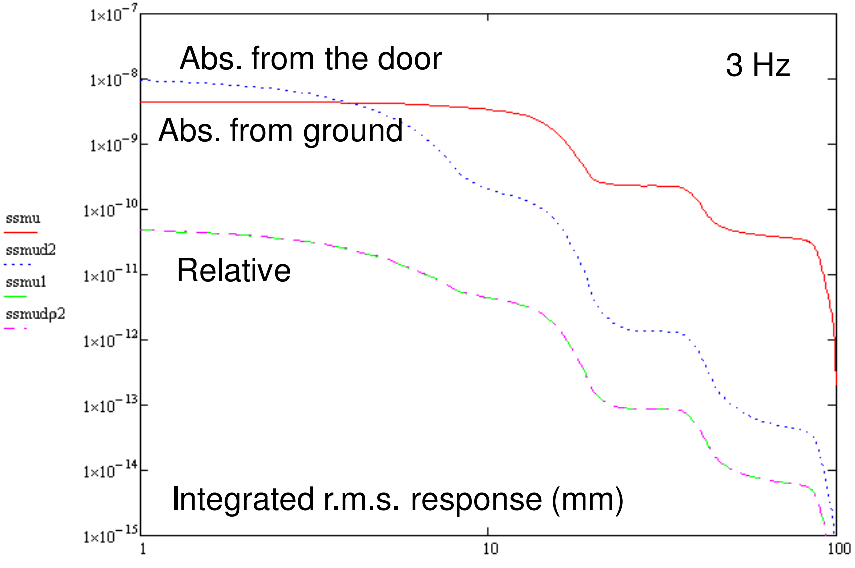
Harmonic Analysis

Frequency Response Function









De-rated Floppy Supports (worst case)

Conclusions

- Both End-Supports and cantilevered support scheme of the Final Focus show acceptable sub-nanometric relative vibration values.
- The End-Supports provide the lowest r.m.s. relative displacements.
- Providing supports from the doors (as in SiD) is perfectly compatible with the nanometric stability requirements.
- It improve the correlation of the PSD relative noise spectra
- It is a natural way to make a passive isolator (large door Mass - low K feet), shifting the high static transmissibility at the floor-detector interface
- It has many advantages like:

    Make the Final Focus system an integral part of the detector

    Allow to get low L*

    Provide insurance of re-alignment in the push-pull

    Simplify the push-pull operation