Test and understanding of the Virgo+MS: analytical model

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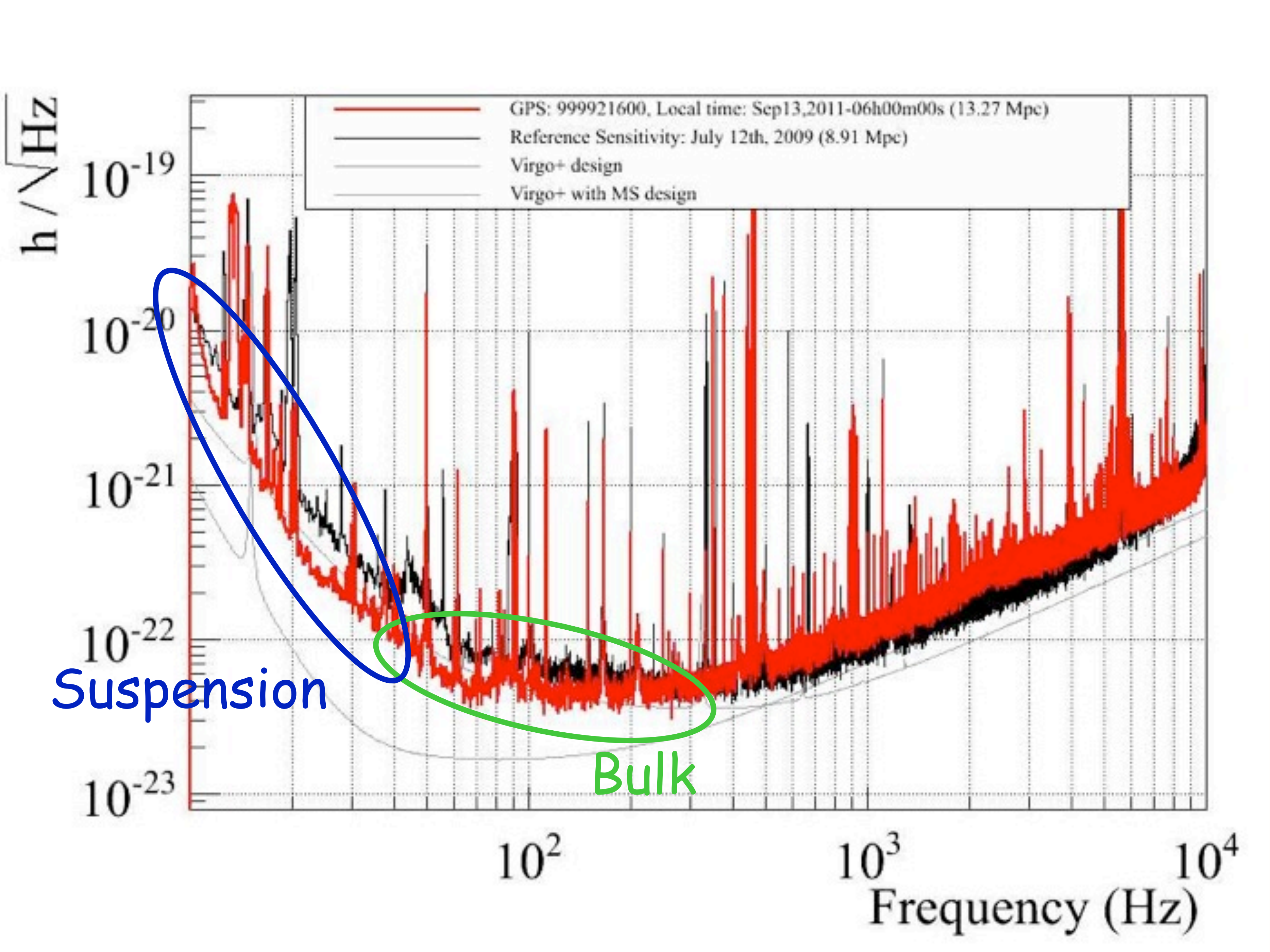
Virgo+MS sensitivity

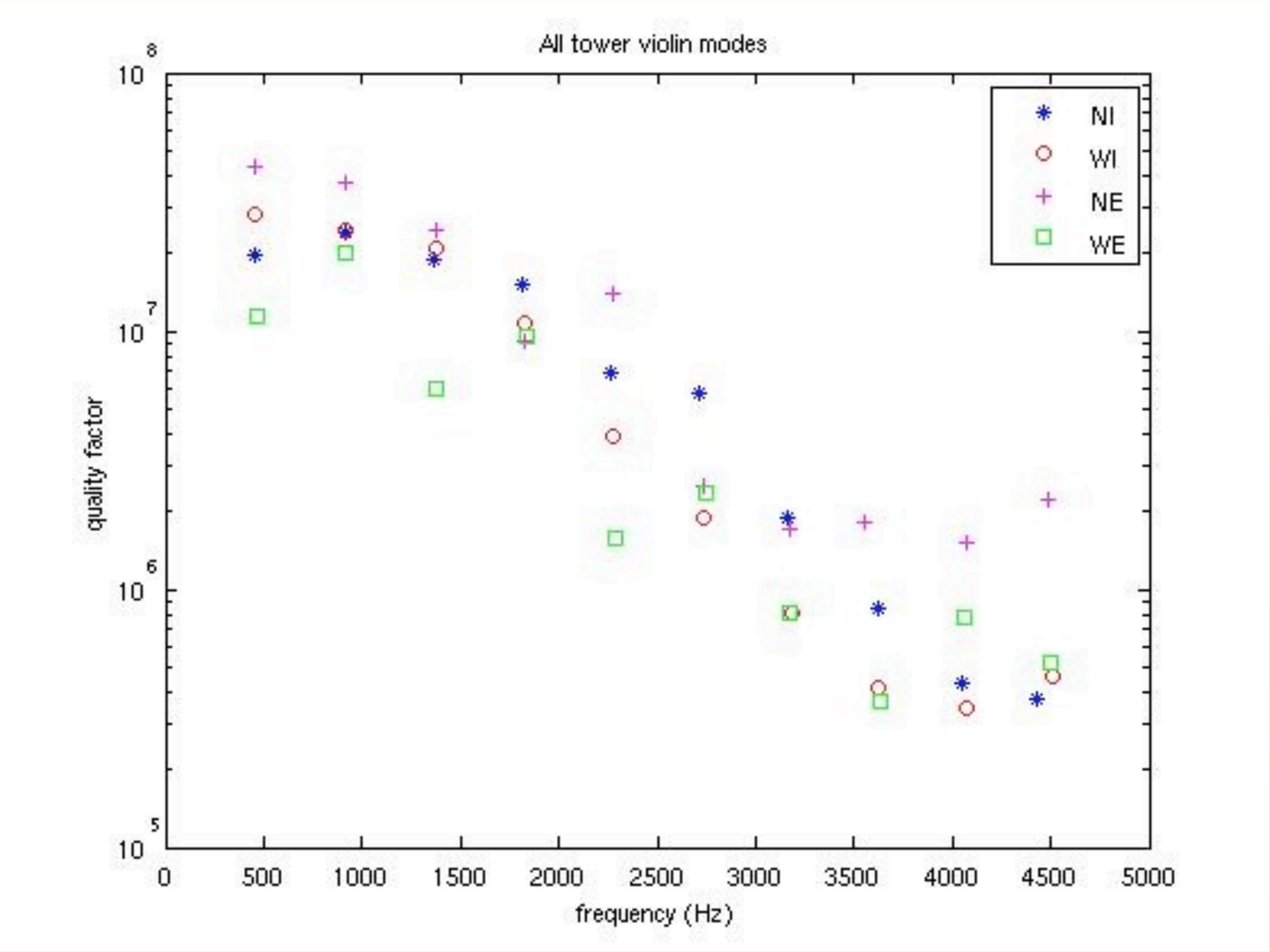


Black curve: Virgo with steel wires

Red curve: Virgo + MS

After MS installation the sensitivity is below the expected steel wire thermal noise.

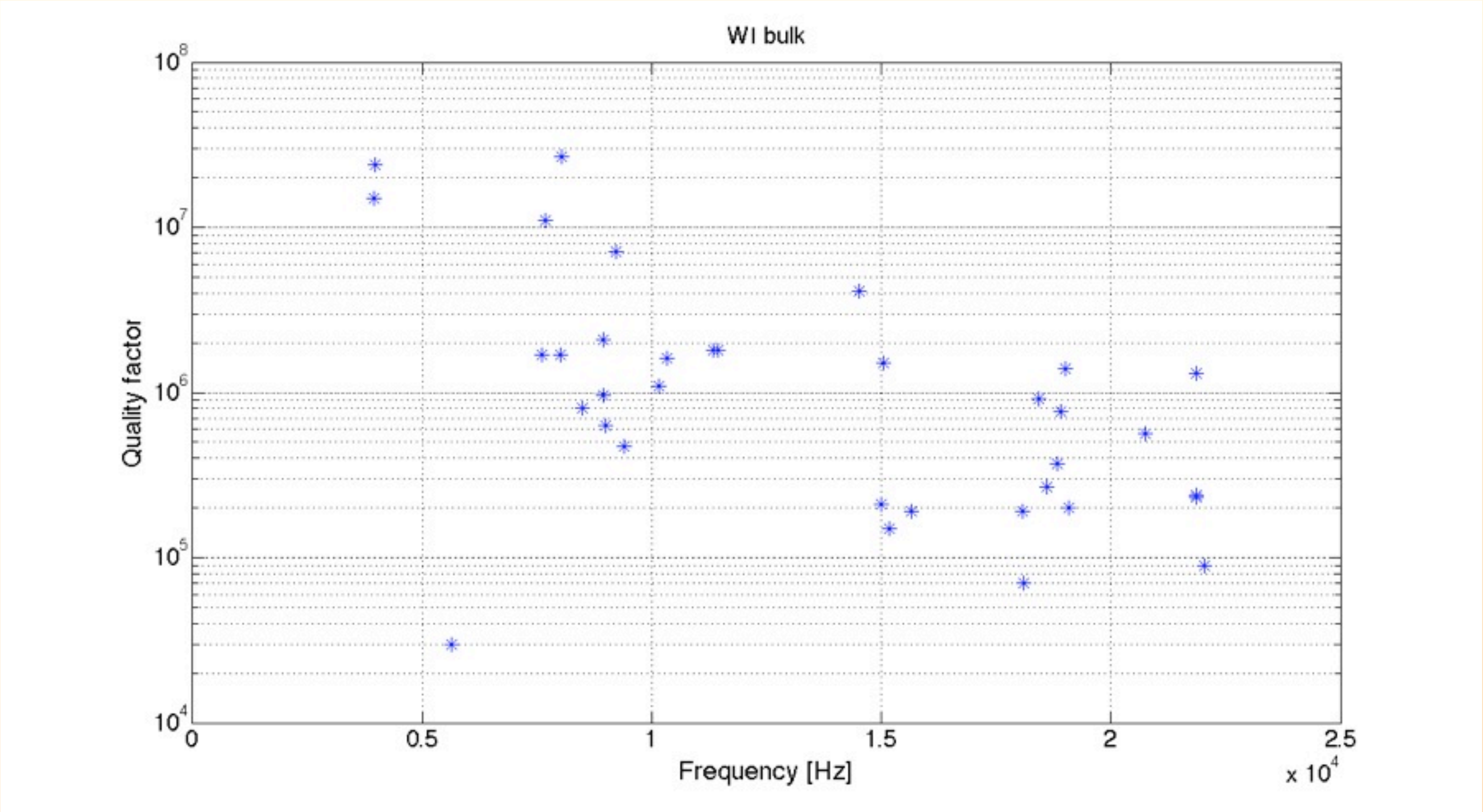
Virgo+MS Violin modes: measured Q



Measured Q values lower than the expected.

Strong decreasing of the values with the frequency.

Virgo+MS Bulk modes: measured Q



Measured Q values lower than the expected.
Large difference among the measured values.

Main questions

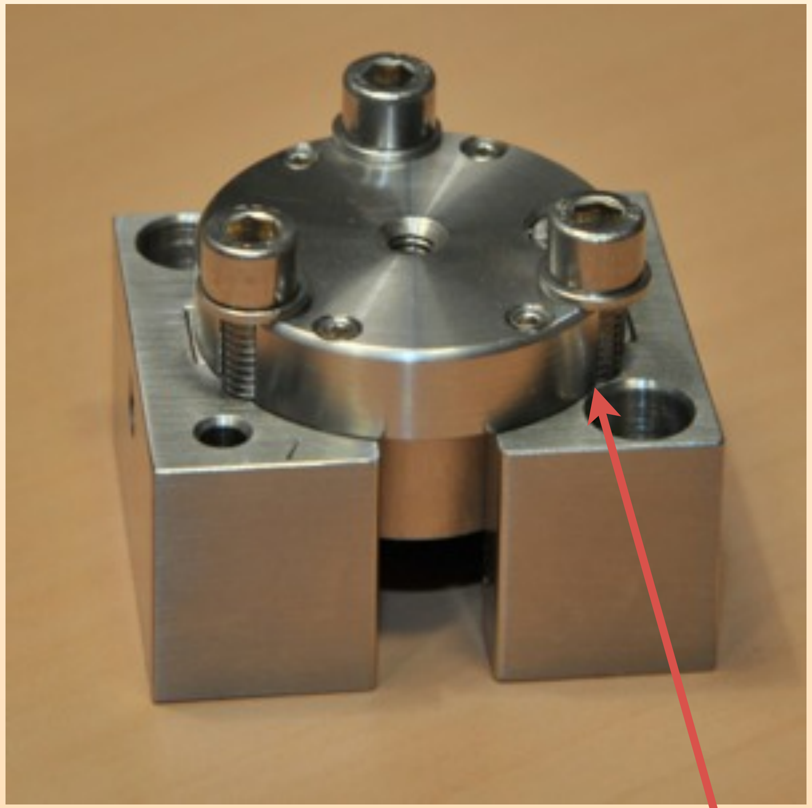
Measured quality factor values lower than the expected ones both for the violin and the bulk modes.

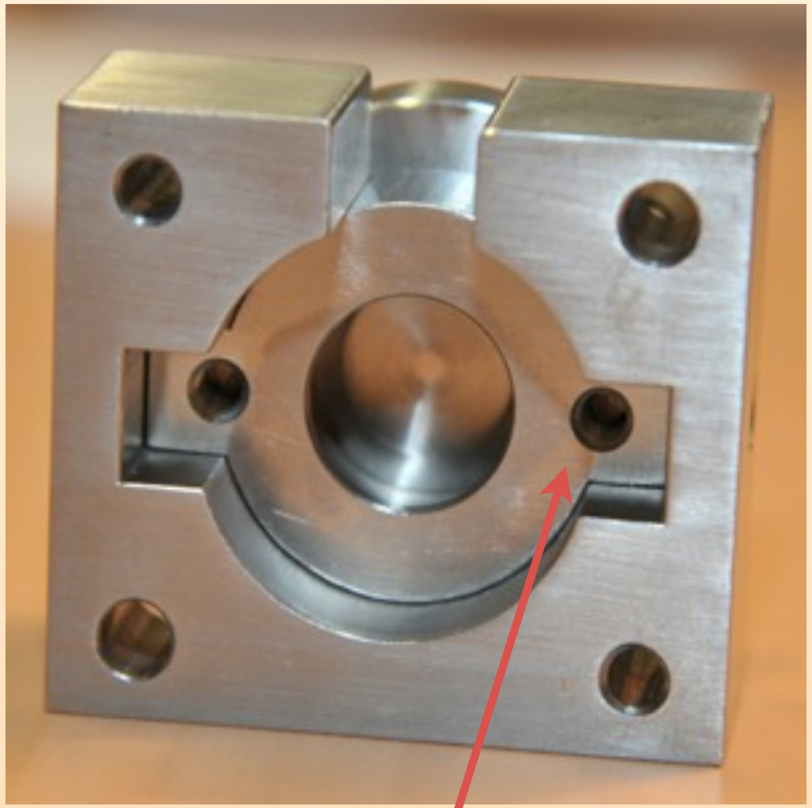
Main question:
- where are the dissipation processes located?

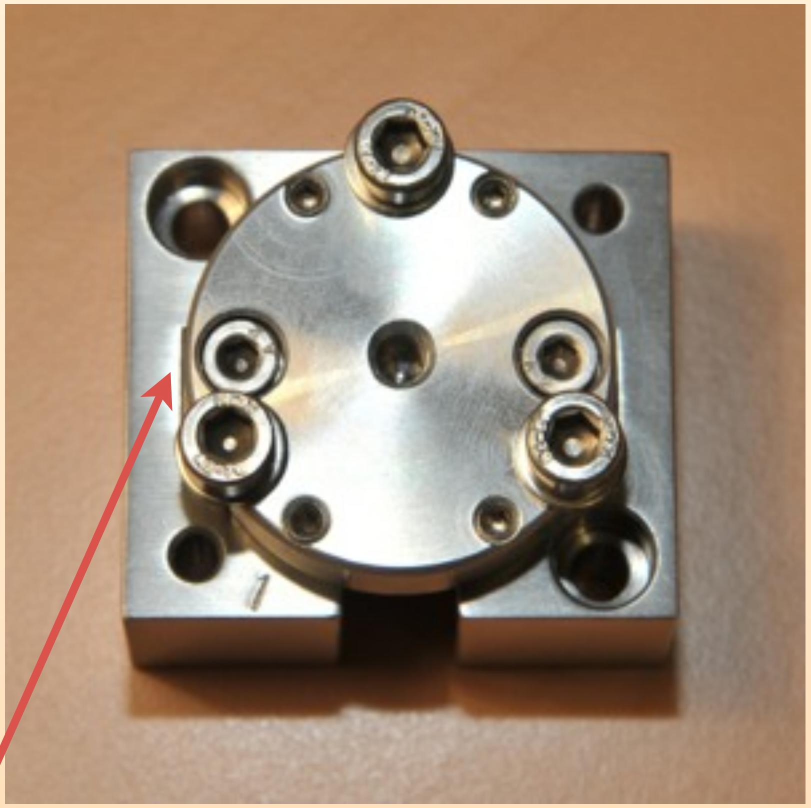
Open questions:
- do the dissipation processes influence the thermal noise?
- is Virgo + limited by thermal noise?

Virgo+MS dissipation processes (I): clamps

The silica wires are connected to the marionette by steel clamps, also used to define the right position in the payload.





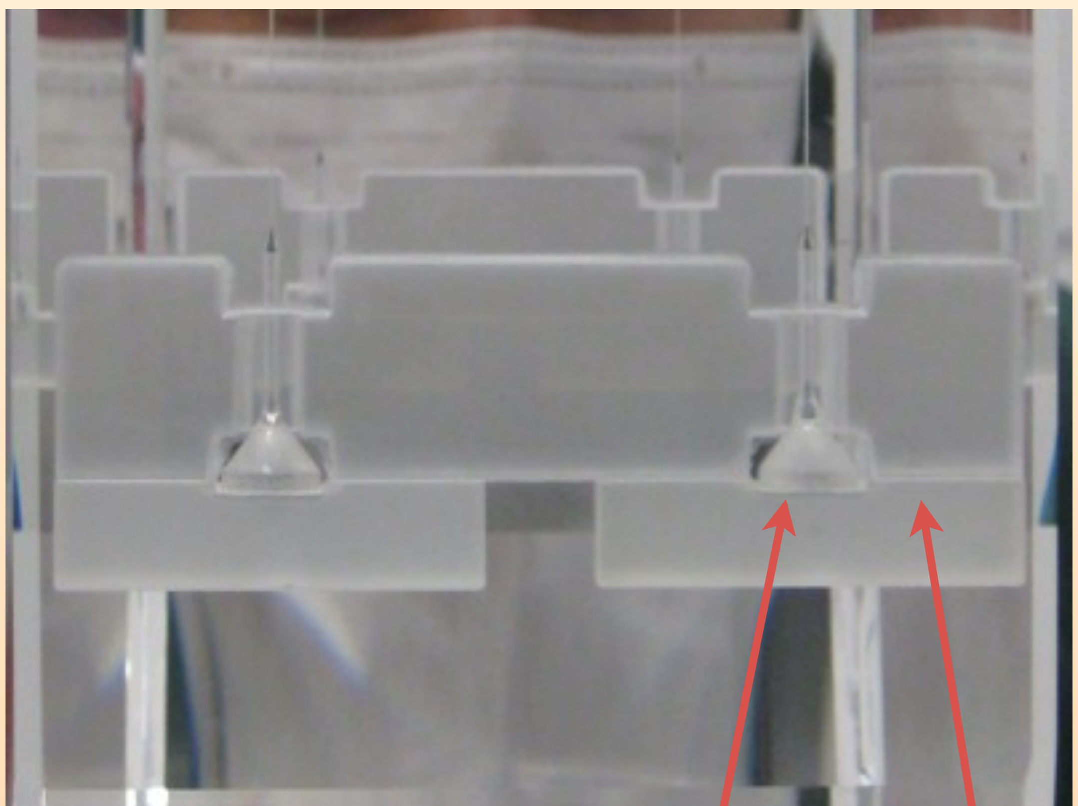


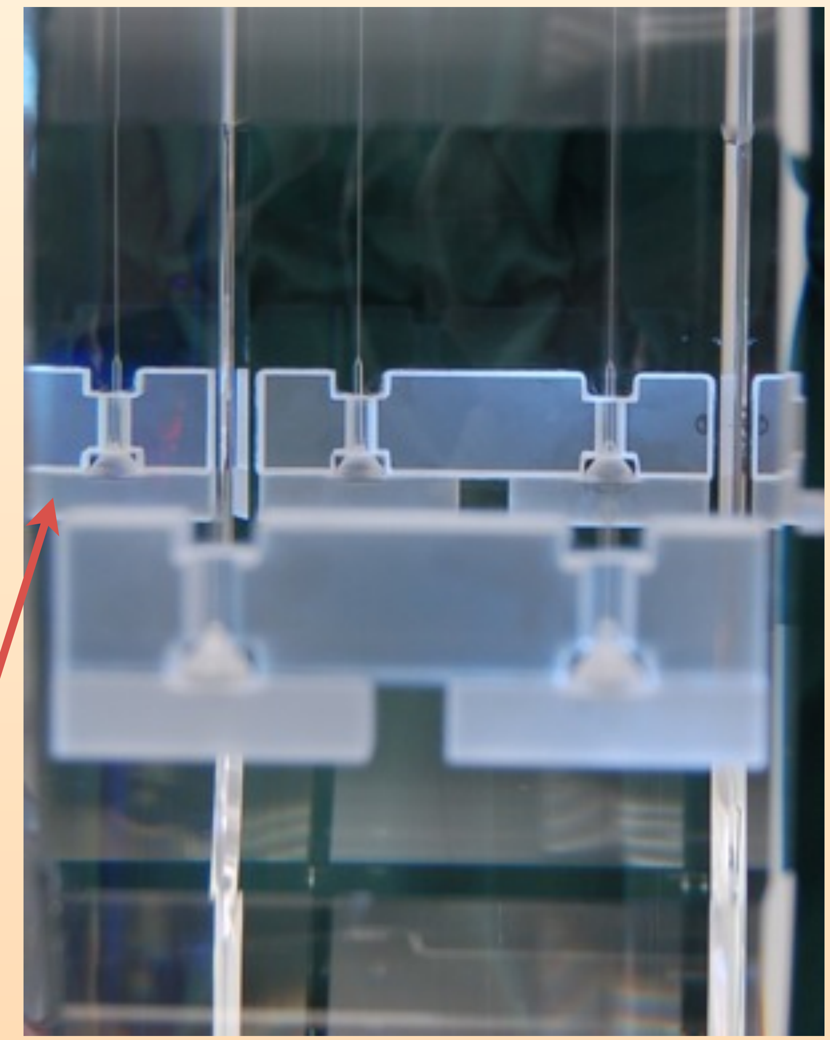
9 screwes in each clamp
possible source of dissipations*

*Cagnoli et al.,Phys. Lett. A 213, 1996

Virgo+MS dissipation processes (II): ears

The silica wires are attached to the mirror by ears.
Modes with a larger displacement of the ear region seem to show a lower Q.

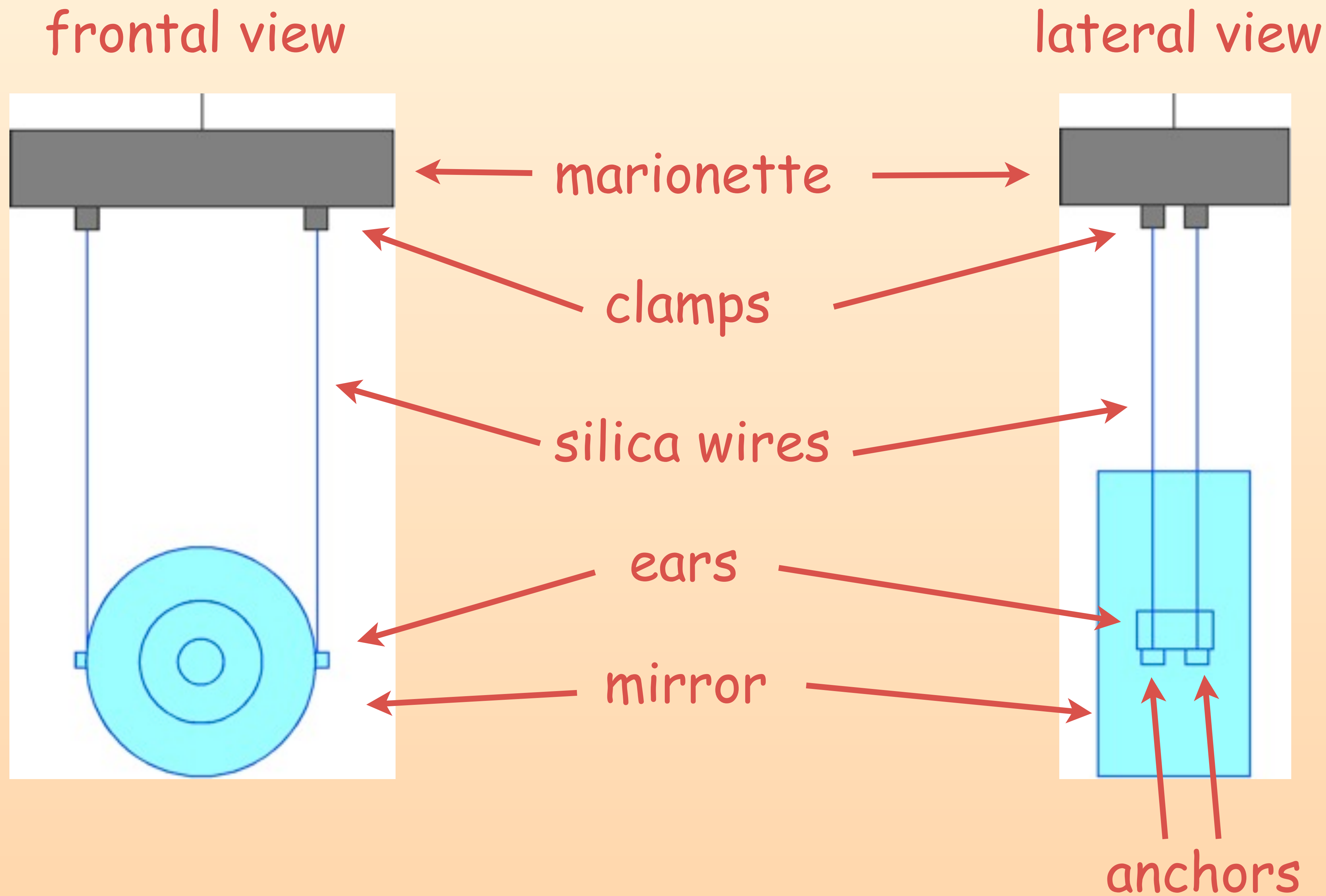




made by several bonded components
possible source of dissipations

Virgo+MS implemented model

Considering the possible sources of dissipations we tried to implement a "realistic" model that can match the quality factor experimental results.



Simulation tool: OCTOPUS (I)

- Use of the mechanical impedance matrices to calculate the different properties of a mechanical system (i.e. transfer functions, resonance frequencies, quality factors, thermal noise,...).

- Analysis of complex systems by combining the impedance matrices of basic systems.

- Basic systems: elastic elements (i.e. wires) and solid bodies (i.e. suspended masses).

- Mechanical properties (i.e. mass, material properties, losses, resonance frequency,...) can be defined for each element.

Simulation tool: OCTOPUS (II)

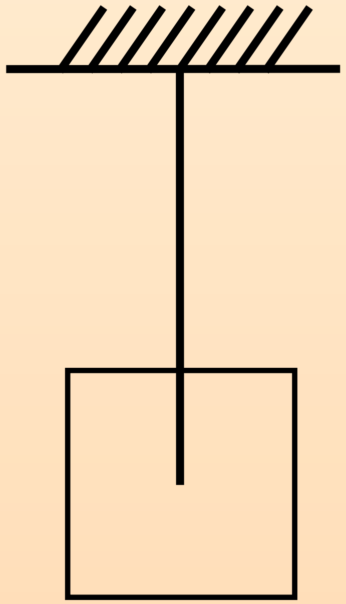
The core of OCTOPUS is the complete description of the wire:

- both the longitudinal and the angular degrees of freedom are considered.
- impedance matrix obtained by the analytical solution of the differential equation that describes the element.
- impedance matrix numerically unstable (introduction of too large numerical errors, divergence)
- renormalization strategy: complete wire connected in parallel with a small wire characterized by an angular resonance around ~ 1 mHz (make the wire numerically evaluable without influence in the results, no more coupling from 100 mHz)

OCTOPUS check

In order to check the OCTOPUS accuracy we compared the obtained results (resonance frequencies, quality factors) for a simple model with the ones evaluated exploiting the method described in "Brownian motion of a mass suspended by an anelastic wire" (Gonzalez, Saulson 1994).

Simple model used for the comparison
- 1 clamped simple wire
- 1 mass



We obtained an accuracy of the order of 10e-5.
We obtained an accuracy of the order of 10e-3.

Virgo+MS implemented model parameters

TEST MASS
m = 20 kg

WIRE
l = 0.7 m
d = 0.285e-3 m
end d = 1.5e-3 m
up end l = 0.012 m
down end l = 0.008 m
losses = 1e-5

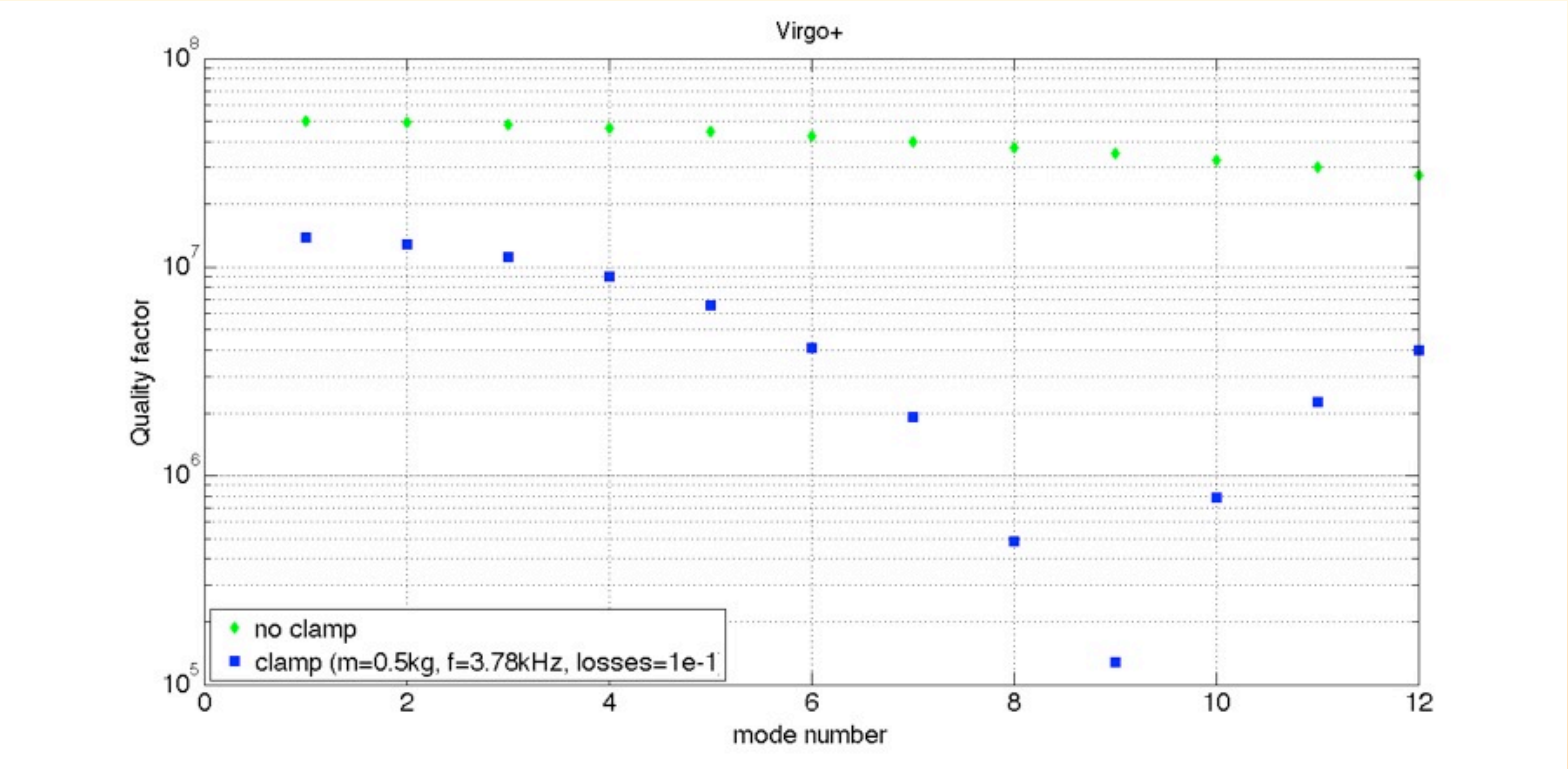
MARIONETTE
m = 105 kg

ANCHOR
m = 0.04 kg
f = 50 kHz
losses = 2e-2

CLAMP
m = 0.5 kg
f = 3.78 kHz (between mode 9 and 10)
losses = 1e-1

(real clamp m = 0.32 kg)

Virgo+MS Violin modes: estimated Q



The trend of the quality factor of the model with the clamps is quite similar to the measured ones. The anchor does not influence the Q estimated values.

Virgo+MS Bulk modes: estimated Q

Analysis of the first drum mode behavior (longitudinal force) by varying the properties of the anchors:

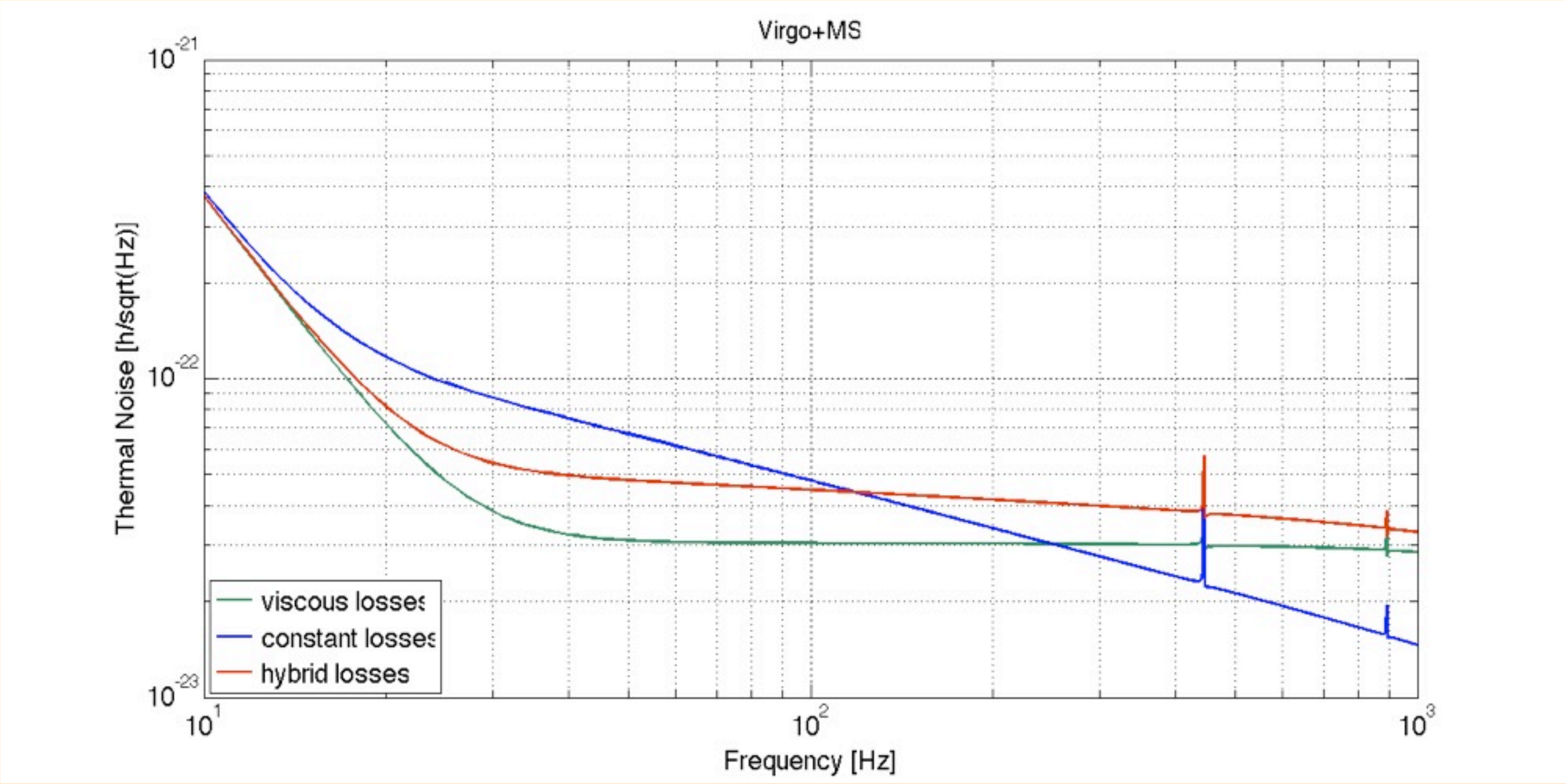
- constant losses (= 5e-2): Q = 5.86e5

- viscous losses (linear dependance on frequency): Q = 6.10e4

- “hybrid” losses (not linear dependance on frequency*): Q = 6.10e4

*Cumming et al., Class. Quan. Grav. 29, 2012

Virgo+MS: estimated thermal noise



Open question: is Virgo + limited by thermal noise?

Conclusions

Measured quality factor values lower than the expected ones both for the violin and the bulk modes.

A "realistic" model of the Virgo+MS paylod has been implemented.

Estimated quality factor values are in agreement with the measured ones.

Possible sources of dissipation have been located.

Still open question: is Virgo + limited by thermal noise?