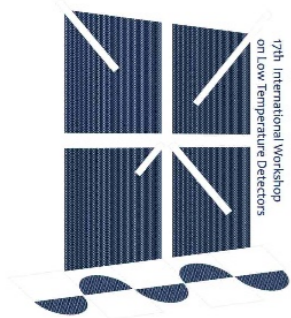


Vibration measurement and mitigation for cryogen- free dilution refrigerator

Chang Lee

17th international workshop
on Low Temperature Detectors
July 2017, Kurume, Fukuoka, Japan



LTD17
July 17-21, 2017
Kurume, Fukuoka, Japan

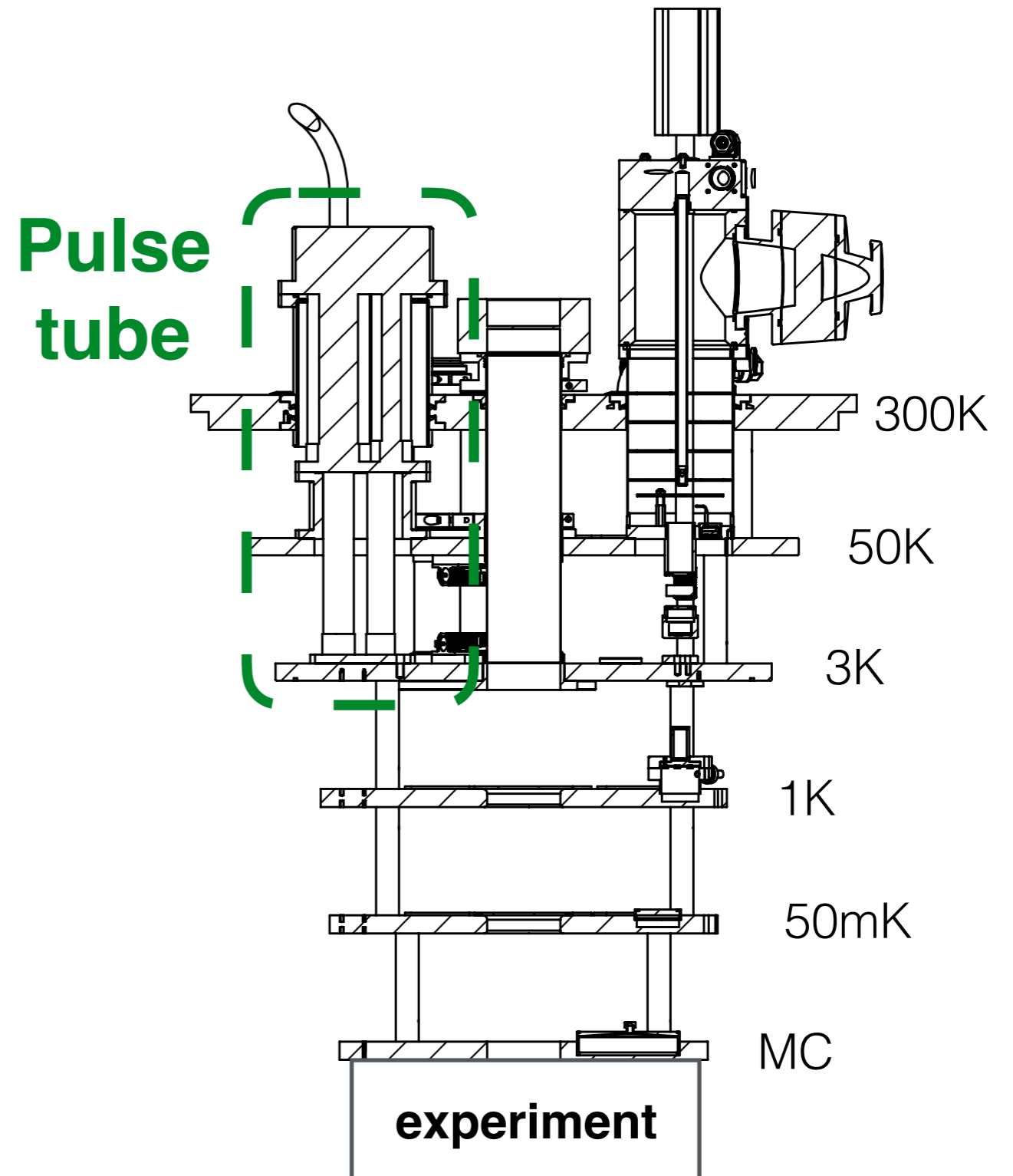
ibs Institute for Basic Science

Cryogen-free DR

Pulse tube refrigerators replace LHe baths.

Easy operation, low maintenance, large experimental space, but..

Mechanical vibration from PTR blocks wider adoption



Pulse tube refrigerator

Cooling power from
adiabatic expansion of
high-pressure helium

Varying pressure:
expansion and contraction of
the SS tube via pressurized He
→ **VIBRATION!!**

~10um, **1.4 Hz** (Cryomech)

K. Uhlig, Cryogenics 42 (2002) 73–77.

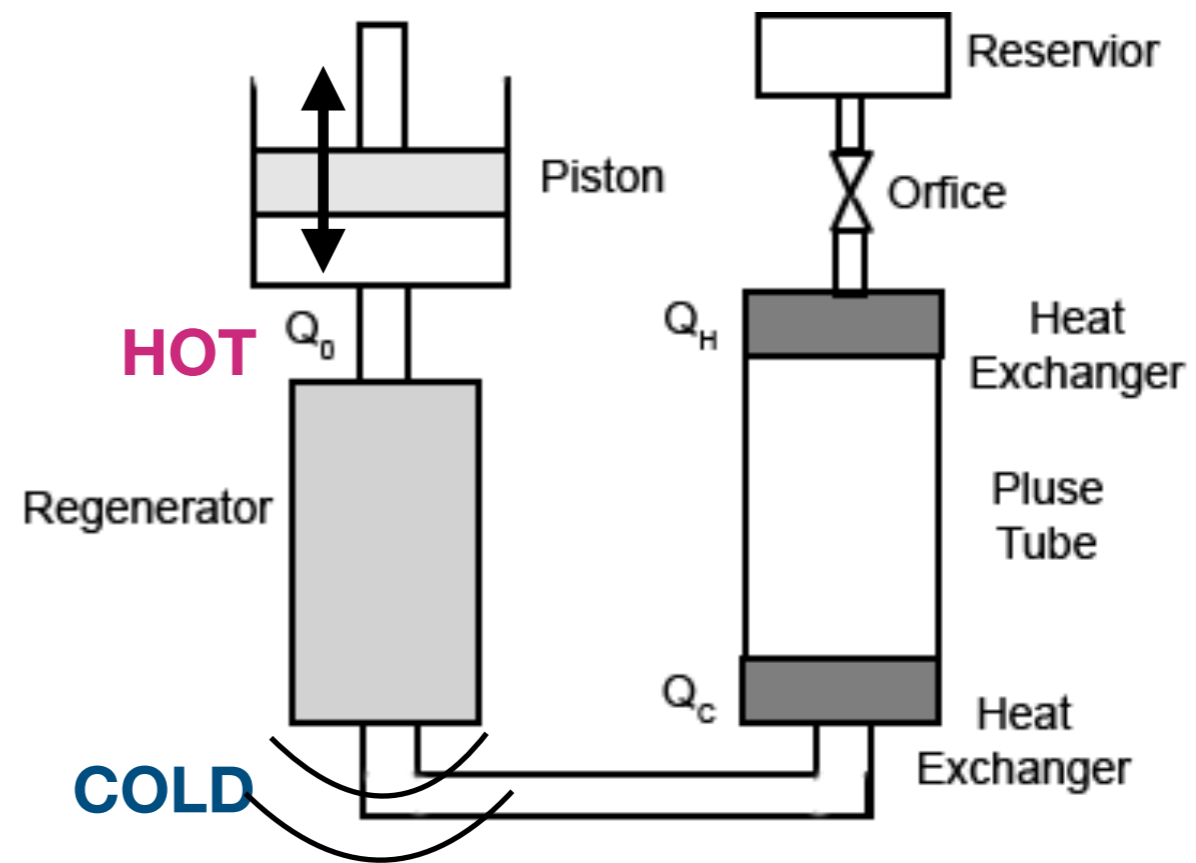


Image from <http://large.stanford.edu/courses/2007/ph210/bert2/>

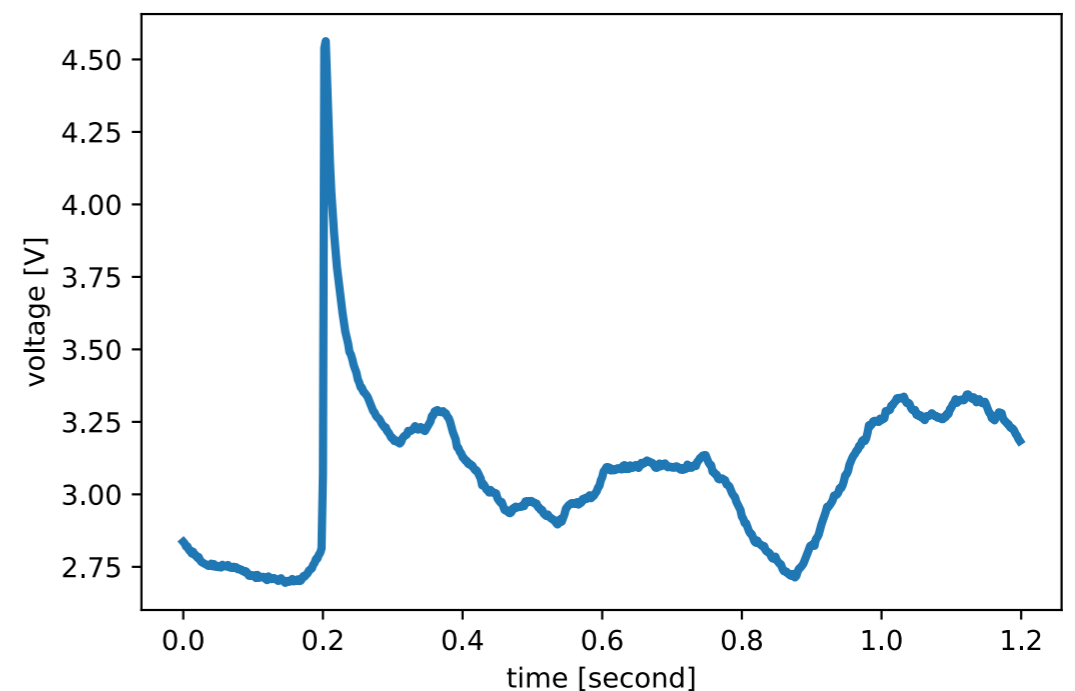
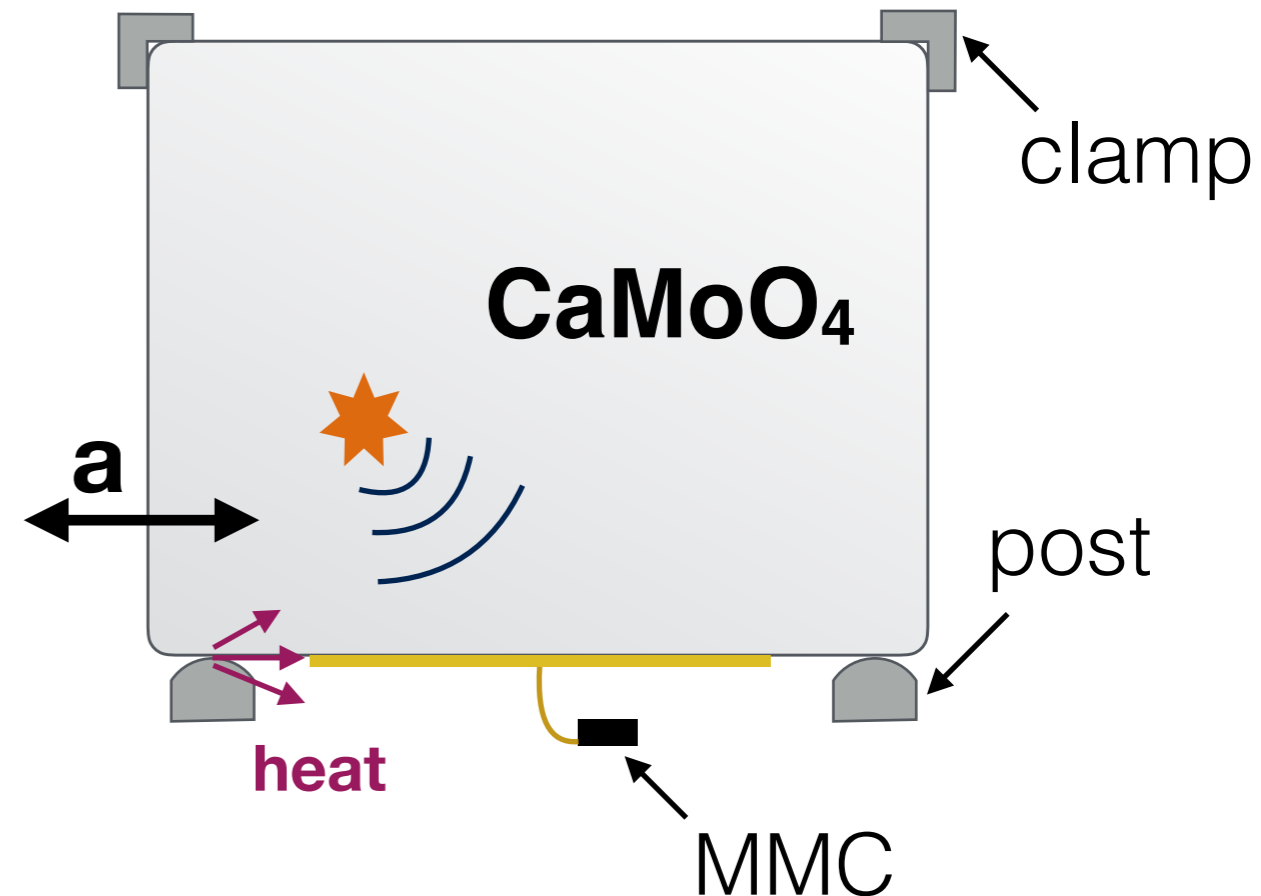
Vibration in AMoRE-pilot

AMoRE:
0-neutrino double beta decay
experiment with MMC.

Acceleration causes **friction**
between CaMoO_4 and posts:
Heat \rightarrow unstable baseline

Vibration from PTR was the
major noise source

Preexisting DR, no Cu braid



Vibration measurement

- Accelerometer
- Geophone (velocity)
- Laser interferometer (displacement)

Large mass &
most LTDs?

high
frequency

microscopy

low
frequency

$$a = \omega_0 \times v = \frac{1}{2} \omega_0^2 \times d$$

Accelerometer

- ENDEVCO 63B
- 1-3000 Hz operation
- Easy installation
- No cryogenic operation

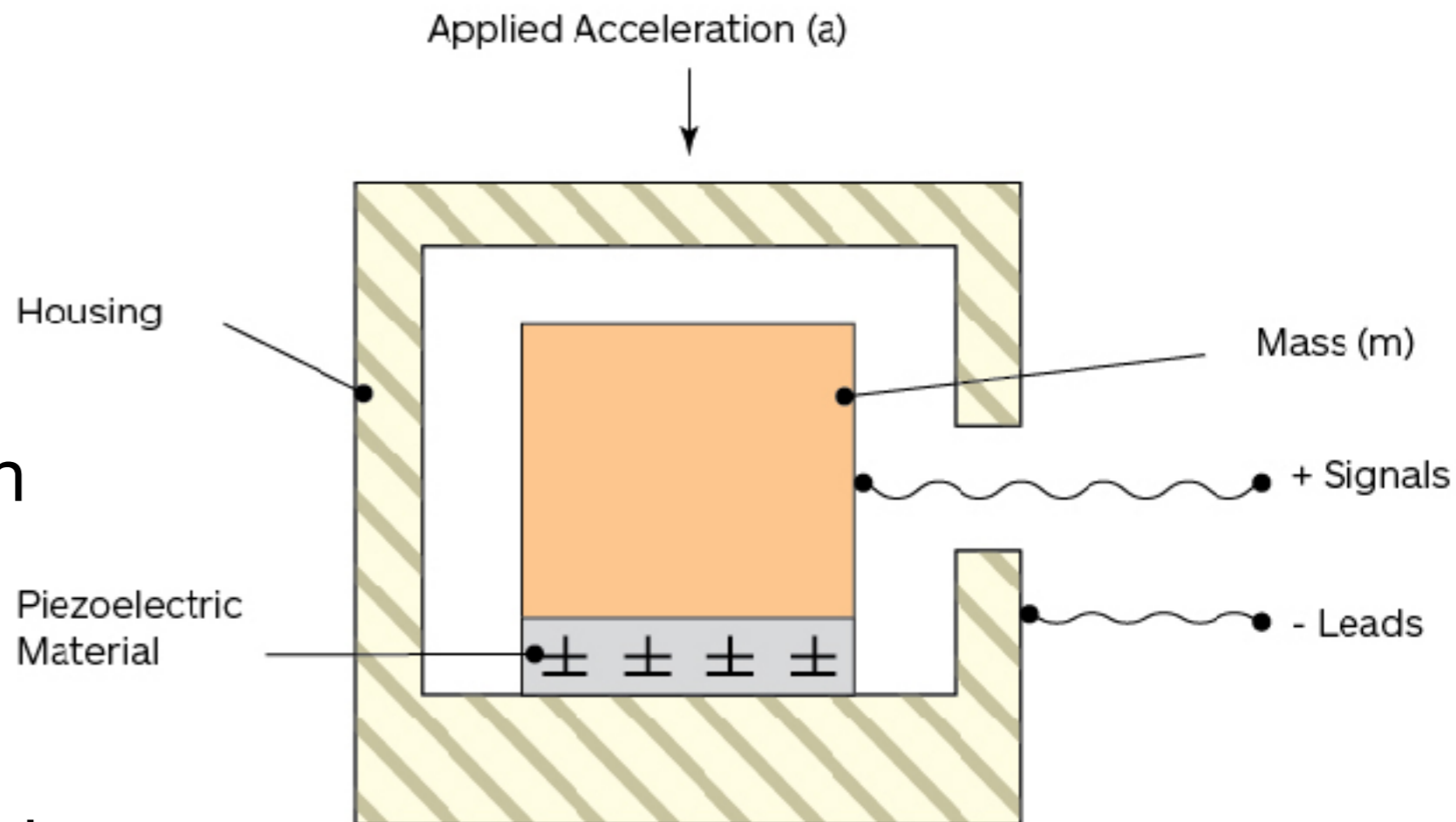


Image from <http://insights.globalspec.com/article/1263/specifying-an-accelerometer-function-and-applications>

Geophone

- Read induced current on coil proportional to **velocity**
- least sensitive
- Geospace GS-11D
- Natural frequency **4.5 Hz**
- **operates at 4K**

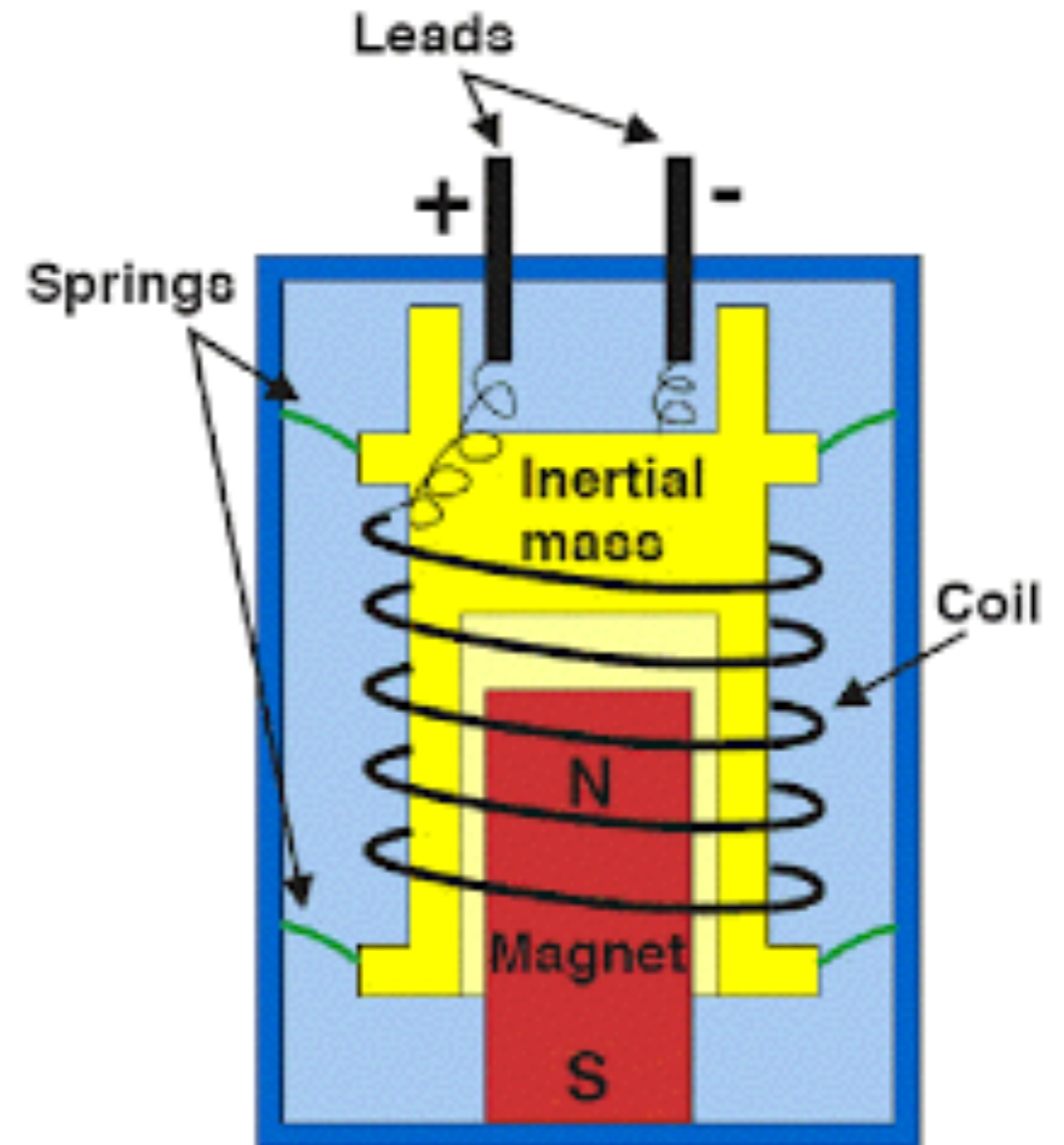
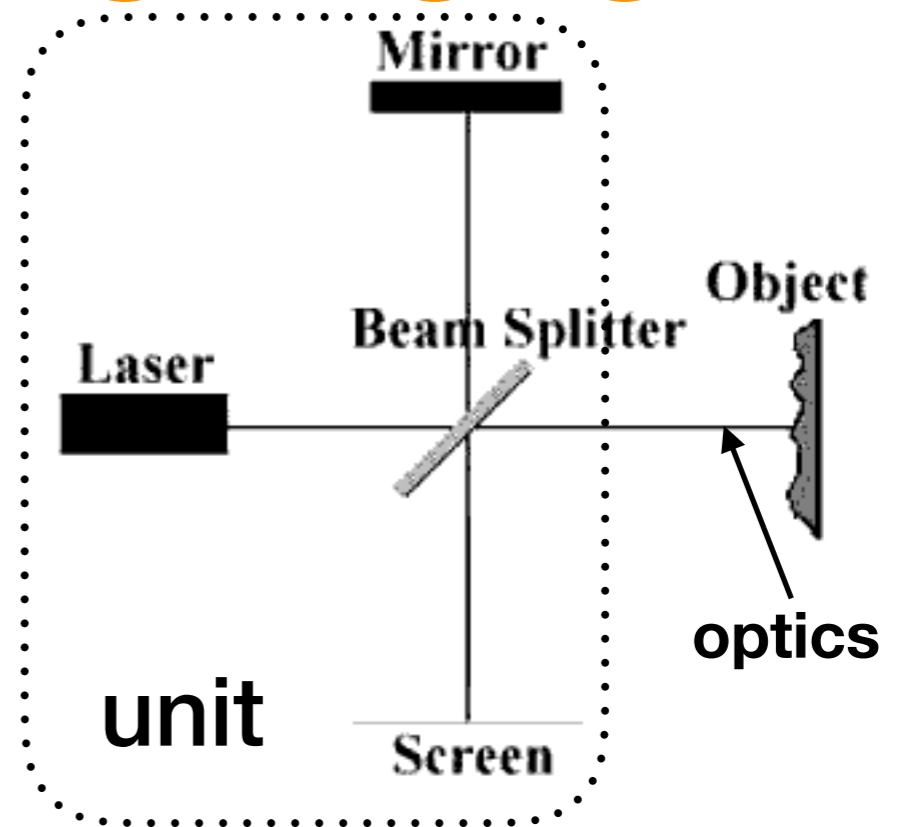


Image from <https://astarmathsandphysics.com/a-level-physics-notes/waves-and-oscillations/3120-the-geophone.html>

Laser interferometer

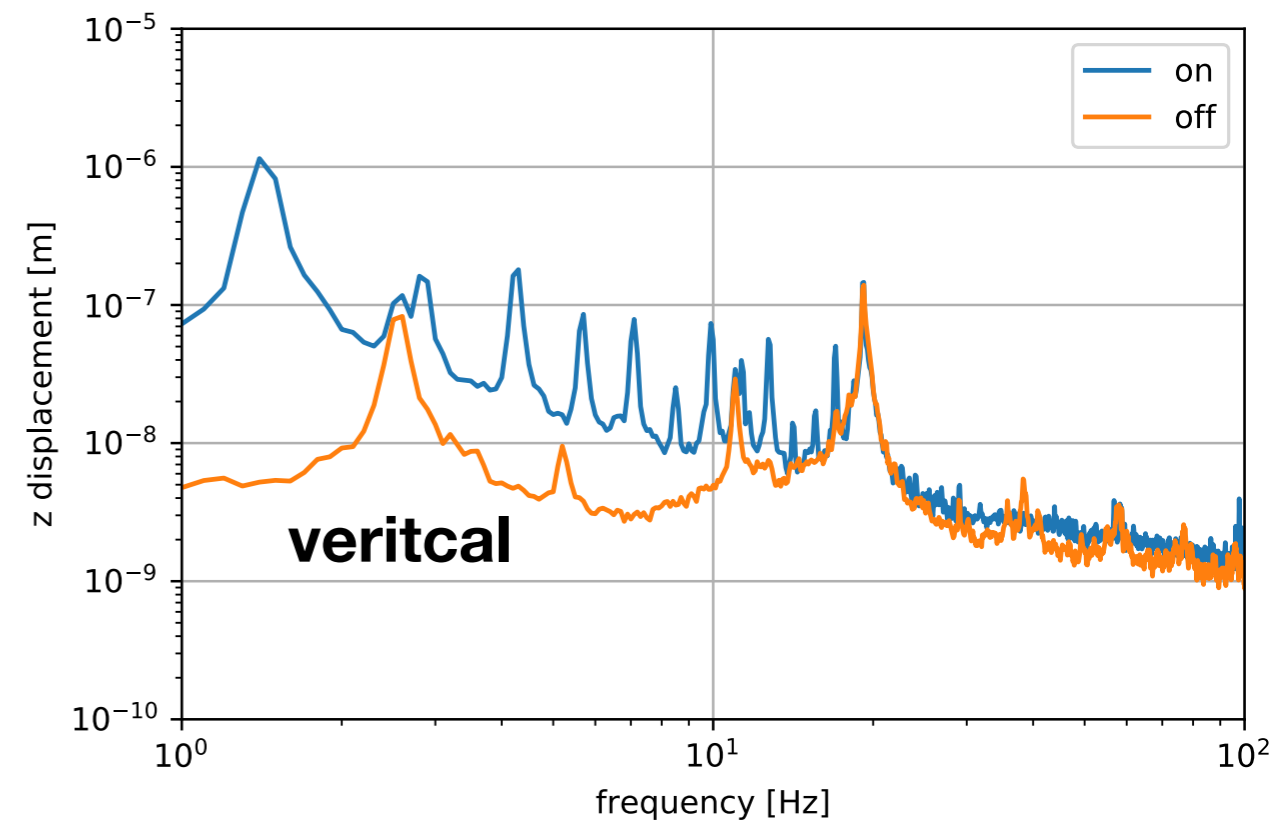
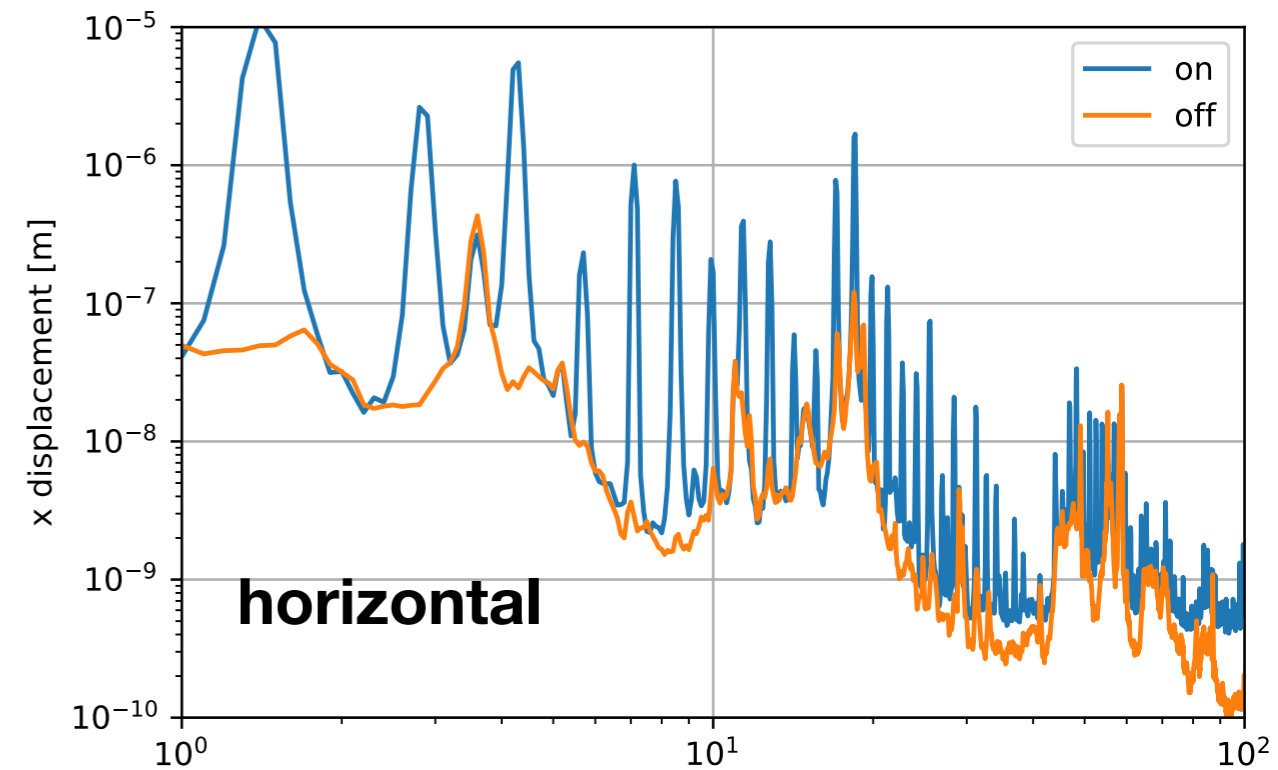
- **displacement** measurement
- DC < bandwidth < 10 MHz
- Difficult installation & alignment
- DR open at room temperature



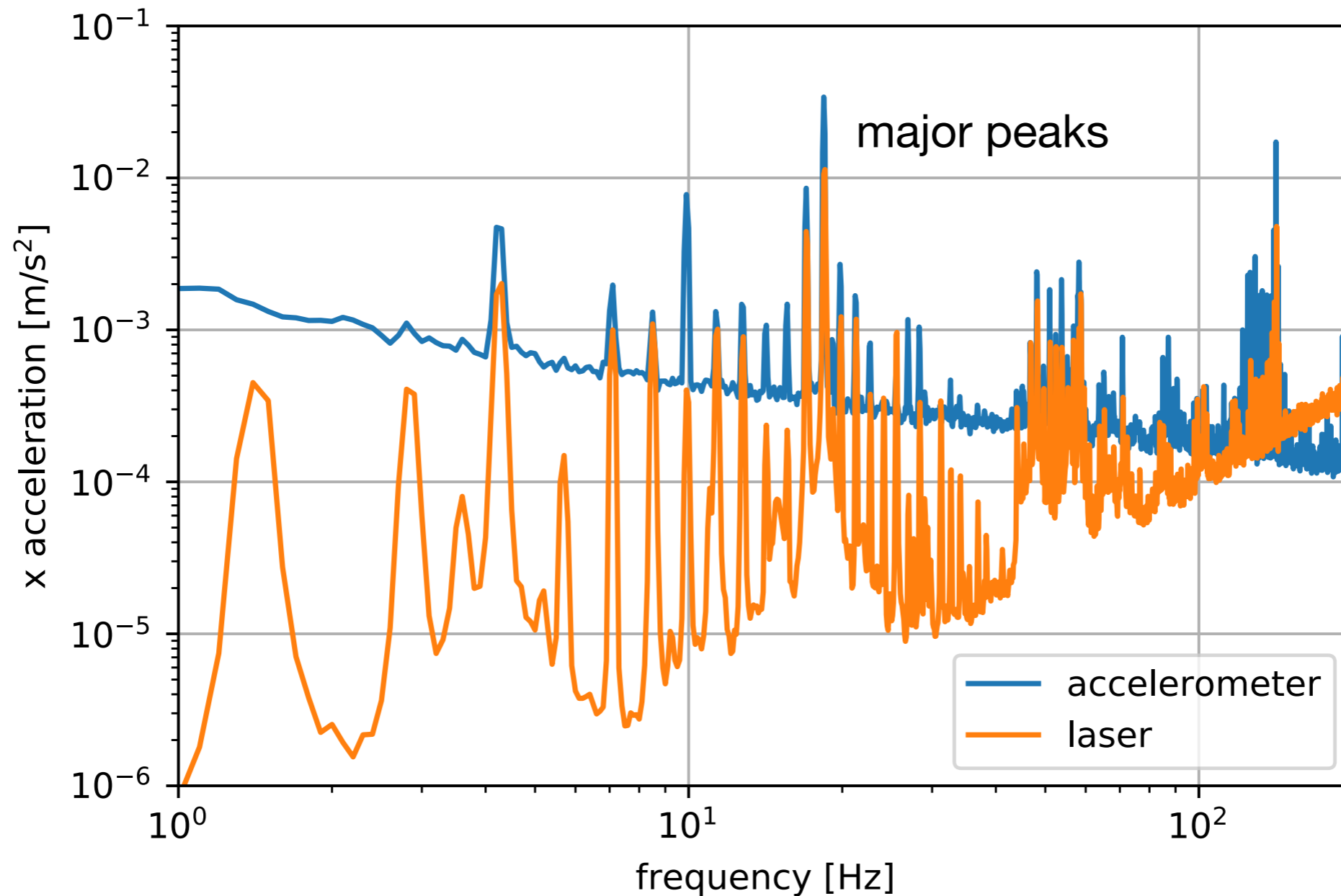
Measurement @ MC

- **Default** Leiden Cryogenics DR
- Freq < 100 Hz dominant
- horizontal >> vertical

rms μm (DC-100 Hz)	horizontal	vertical
PTR off	0.2	0.1
PTR on	5.4	0.5



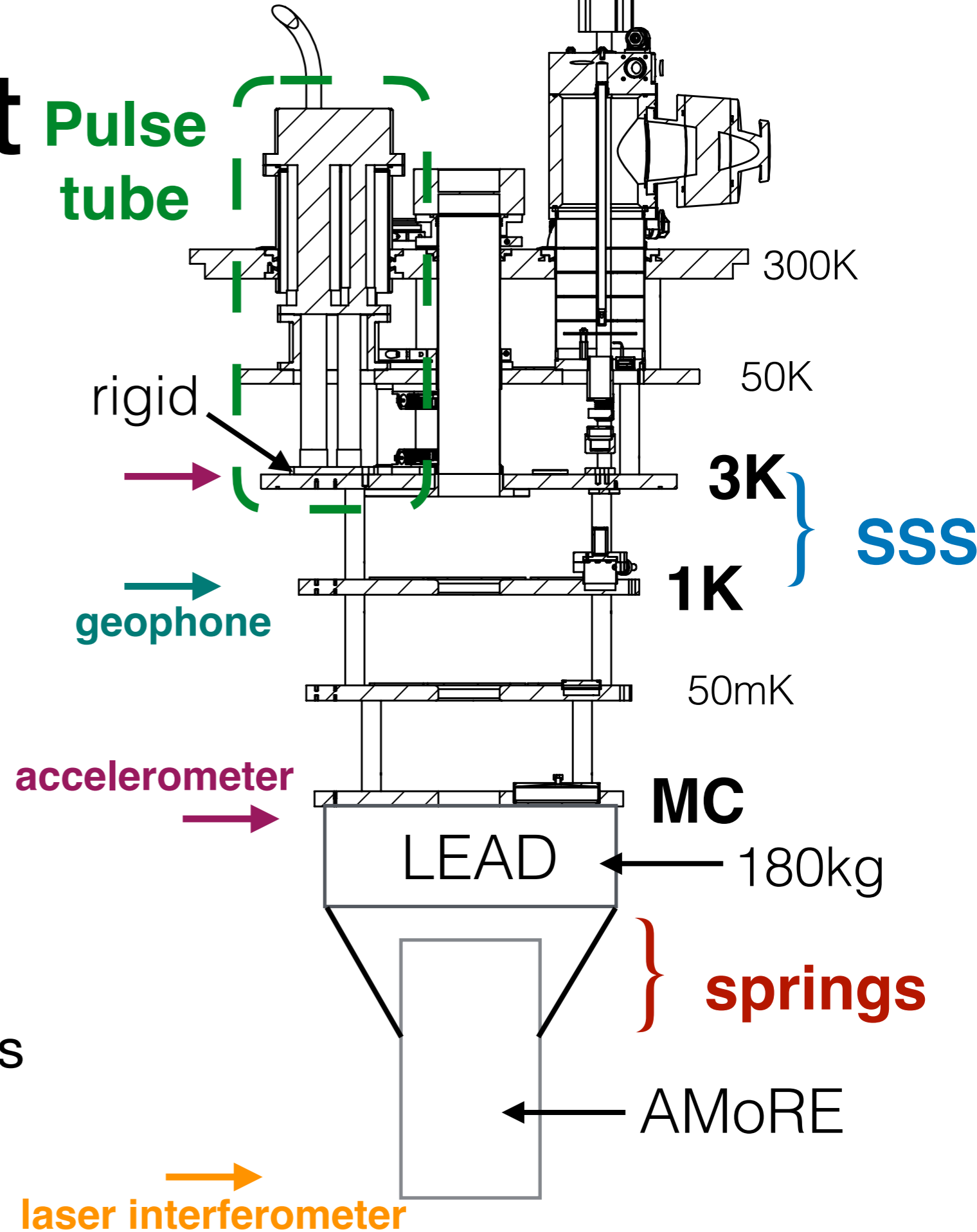
Displacement vs. accelerations



Geophones were much less sensitive.

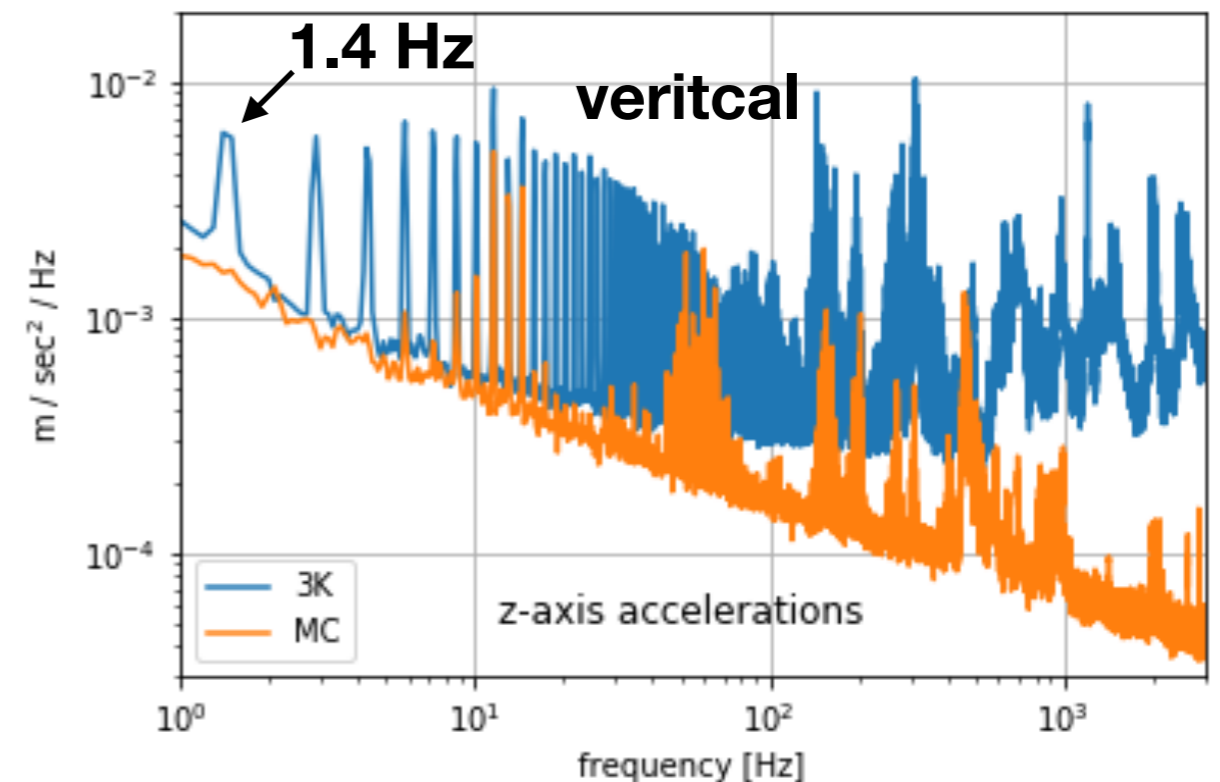
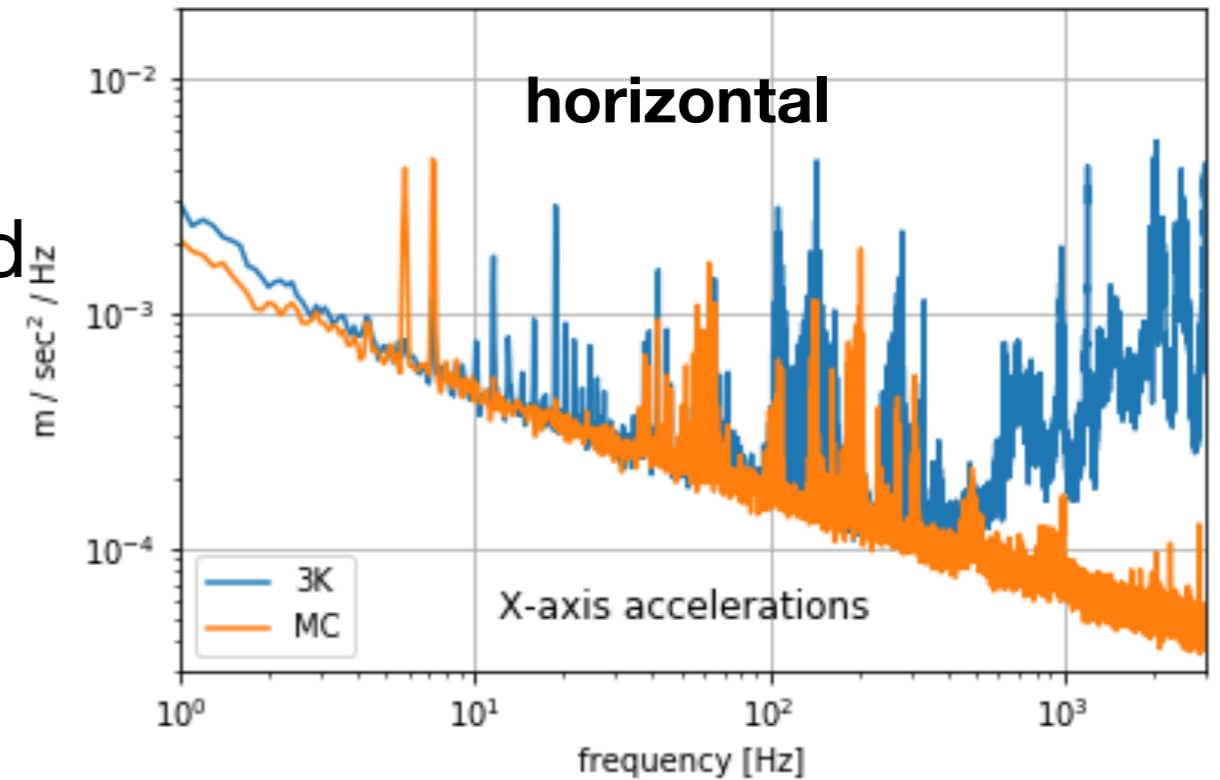
Measurement Setup

- Leiden Cryogenics CF-1400 model
- Cryomech PT-415
- No Cu braid
 - 3K temperature ~4K
 - Vibration isolation less effective



Accelerometer results

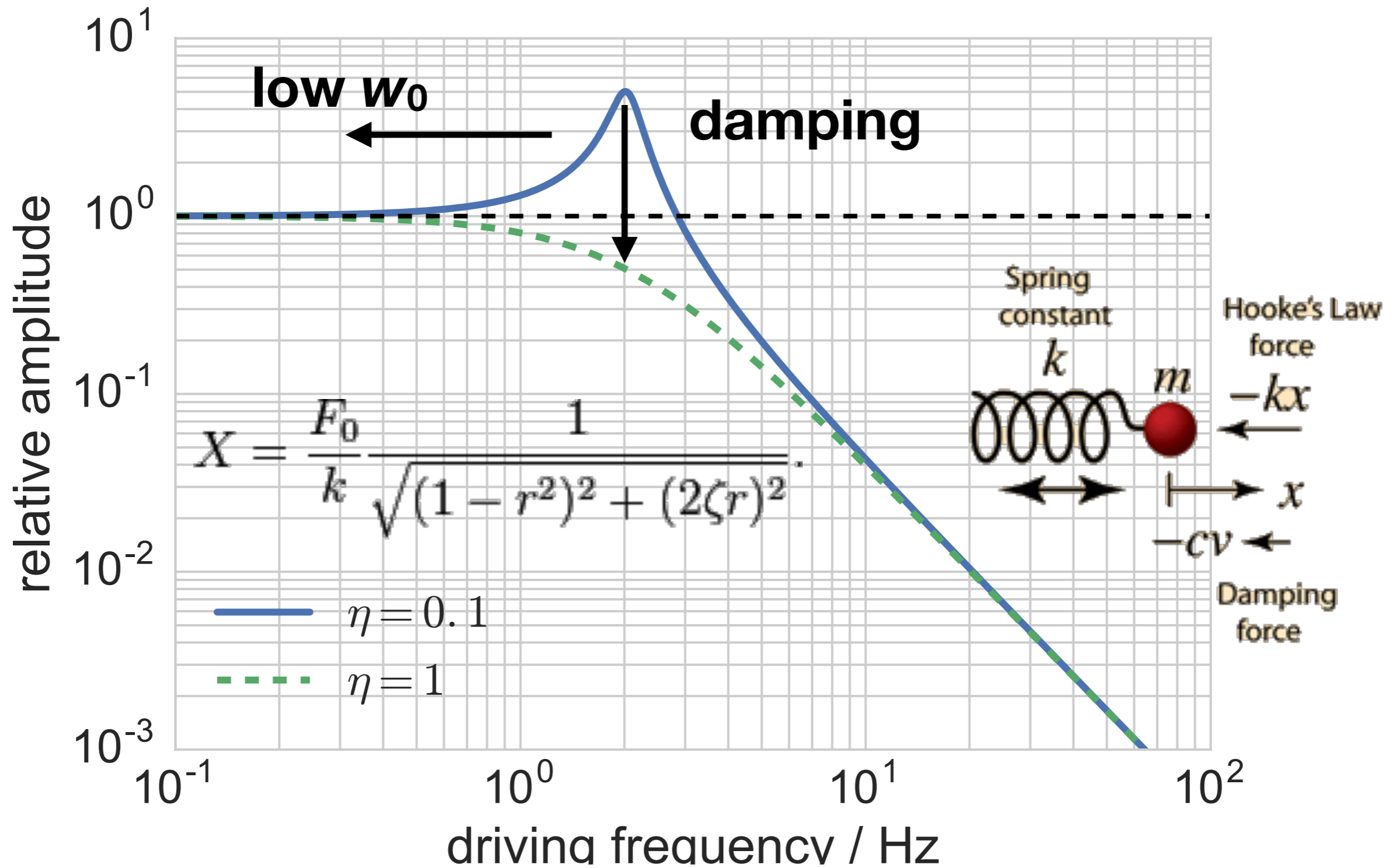
- Initial PT vibration strong @ 3K.
- Extra ~180kg significantly reduced accelerations @ MC
- Horizontal vibrations significant @ mixing chamber



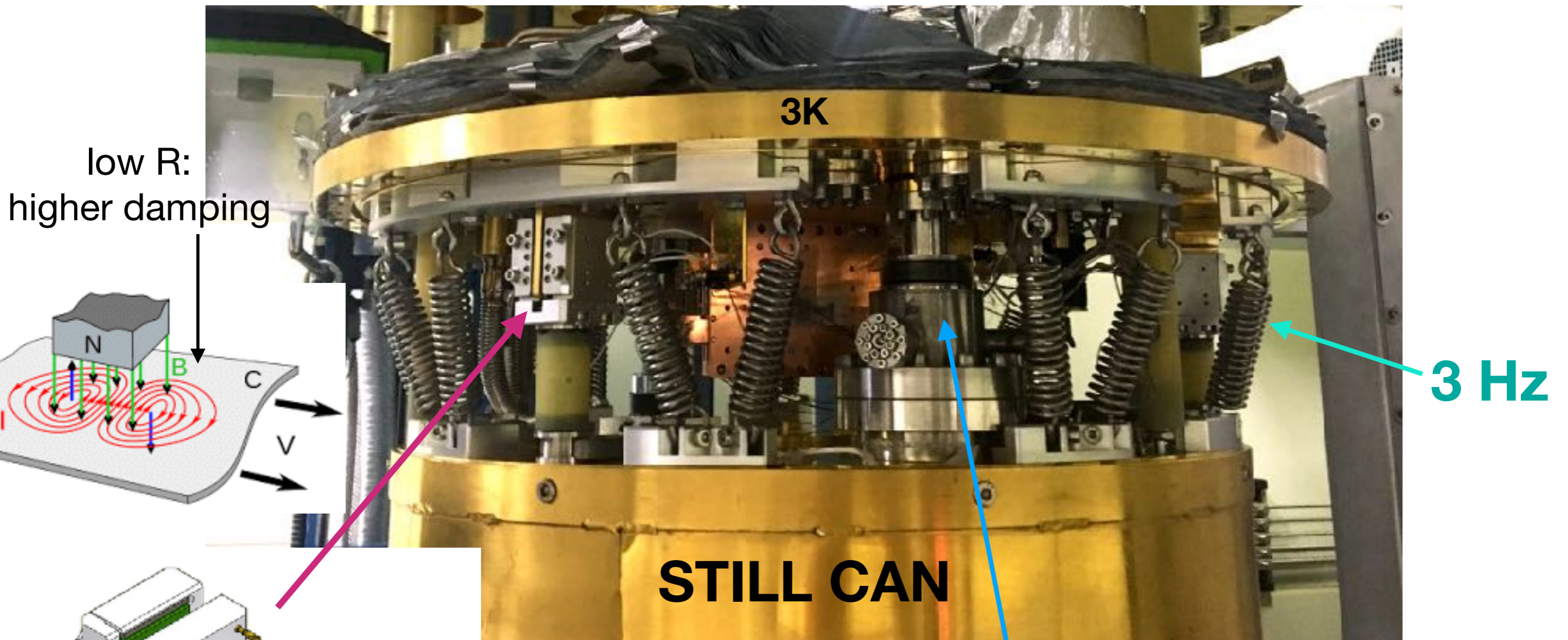
rms mm/sec ² (1-3000 Hz)	horizontal	vertical
3K	56	63
MC	6.4	7.8
PTR off	5.3	5.4

Vibration Isolation

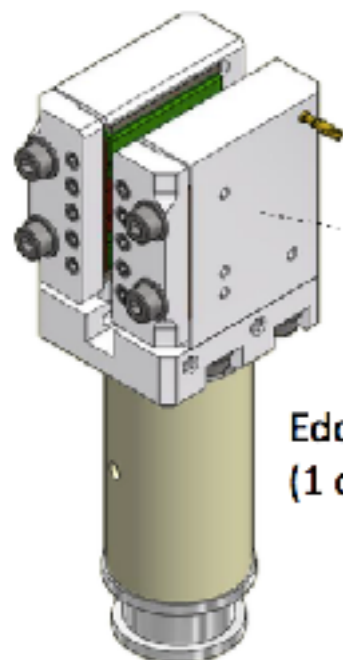
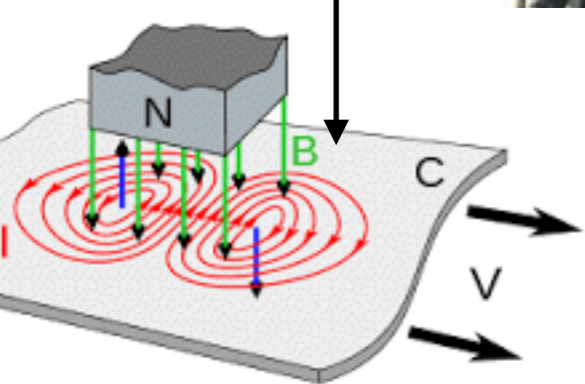
Driven oscillator



Spring-suspended still



low R:
higher damping



Eddy Current Damper
(1 out of 3 in total)

Heat transfer by LHe in still:
No cooling power loss!

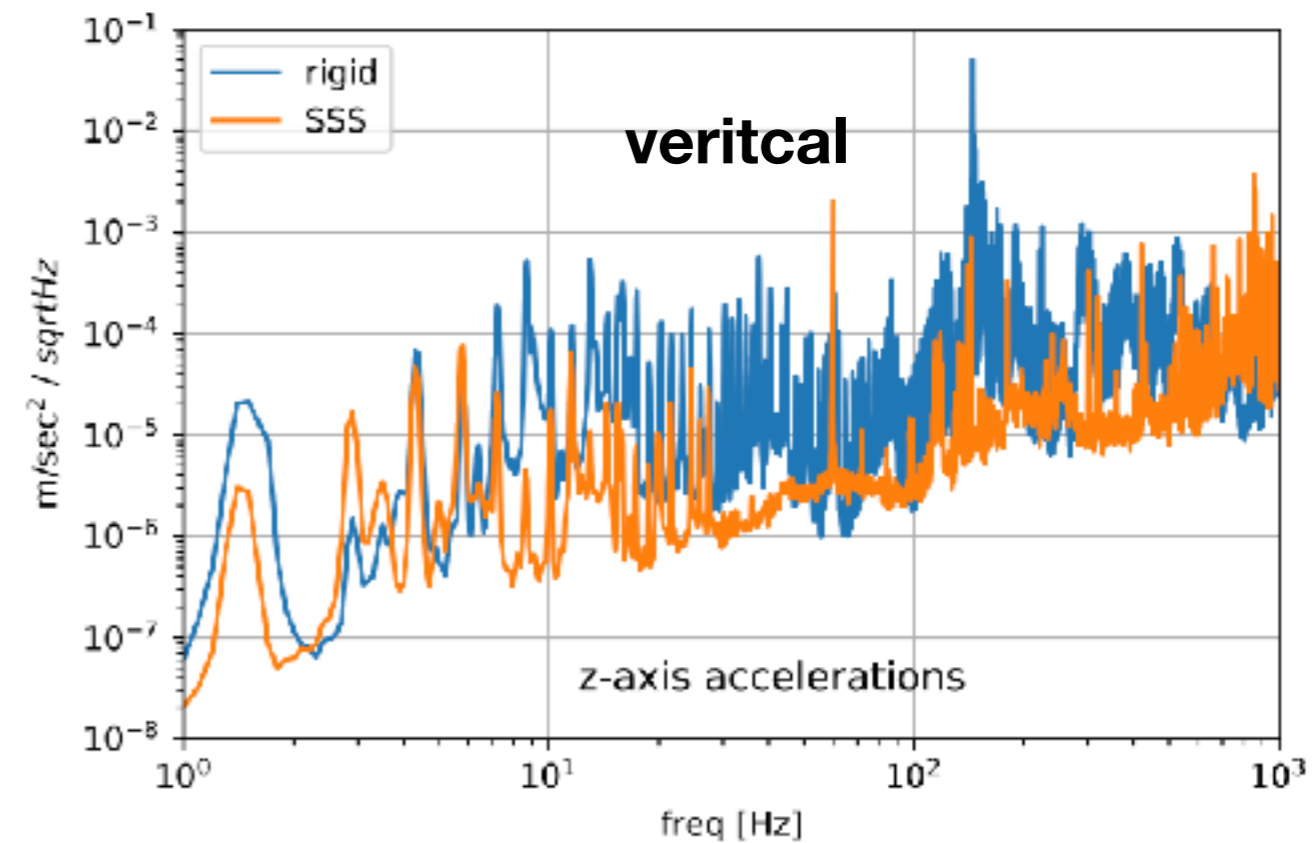
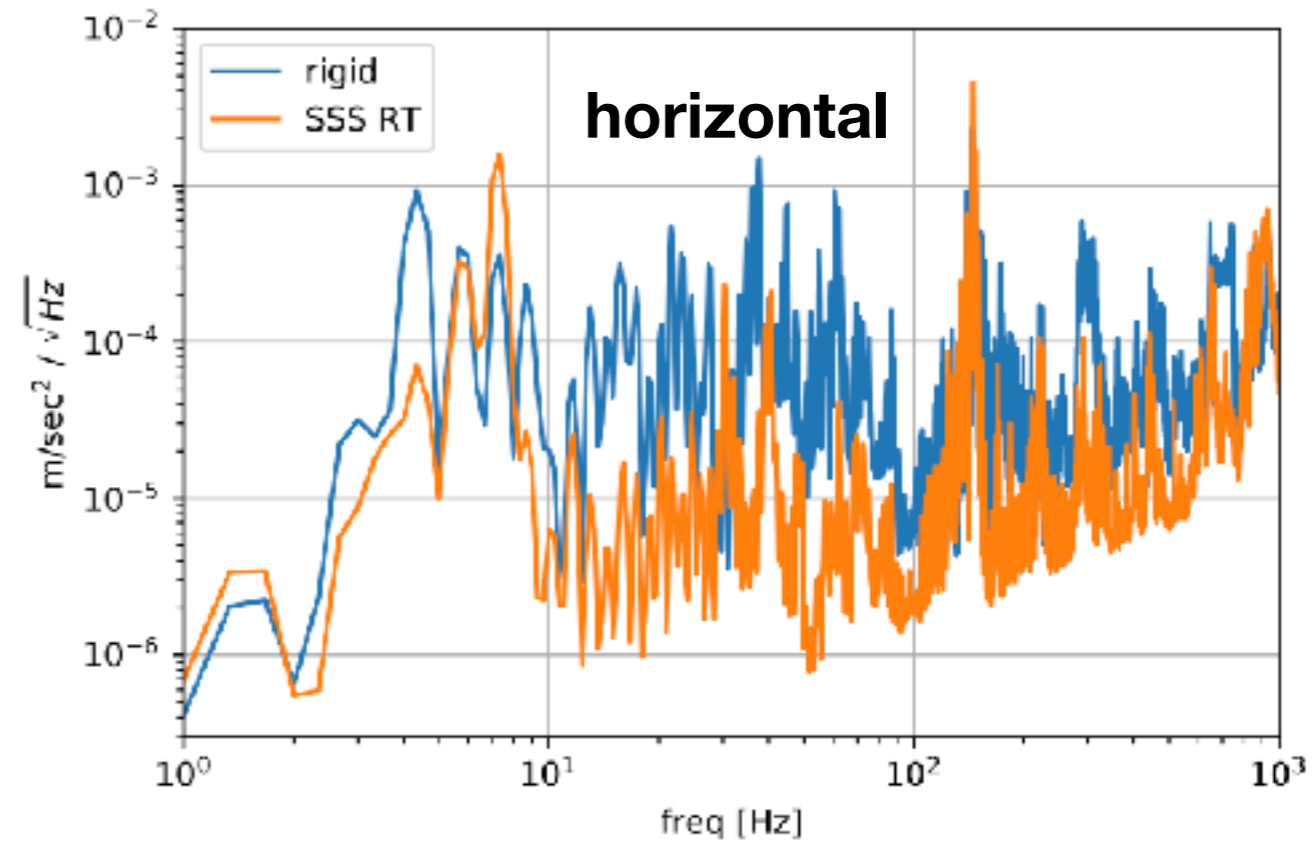
original: **Rev. Sci. Instrum. 85 (2014) 035112.**
Design, fab, & installation by **Leiden Spin Imaging**

SSS results

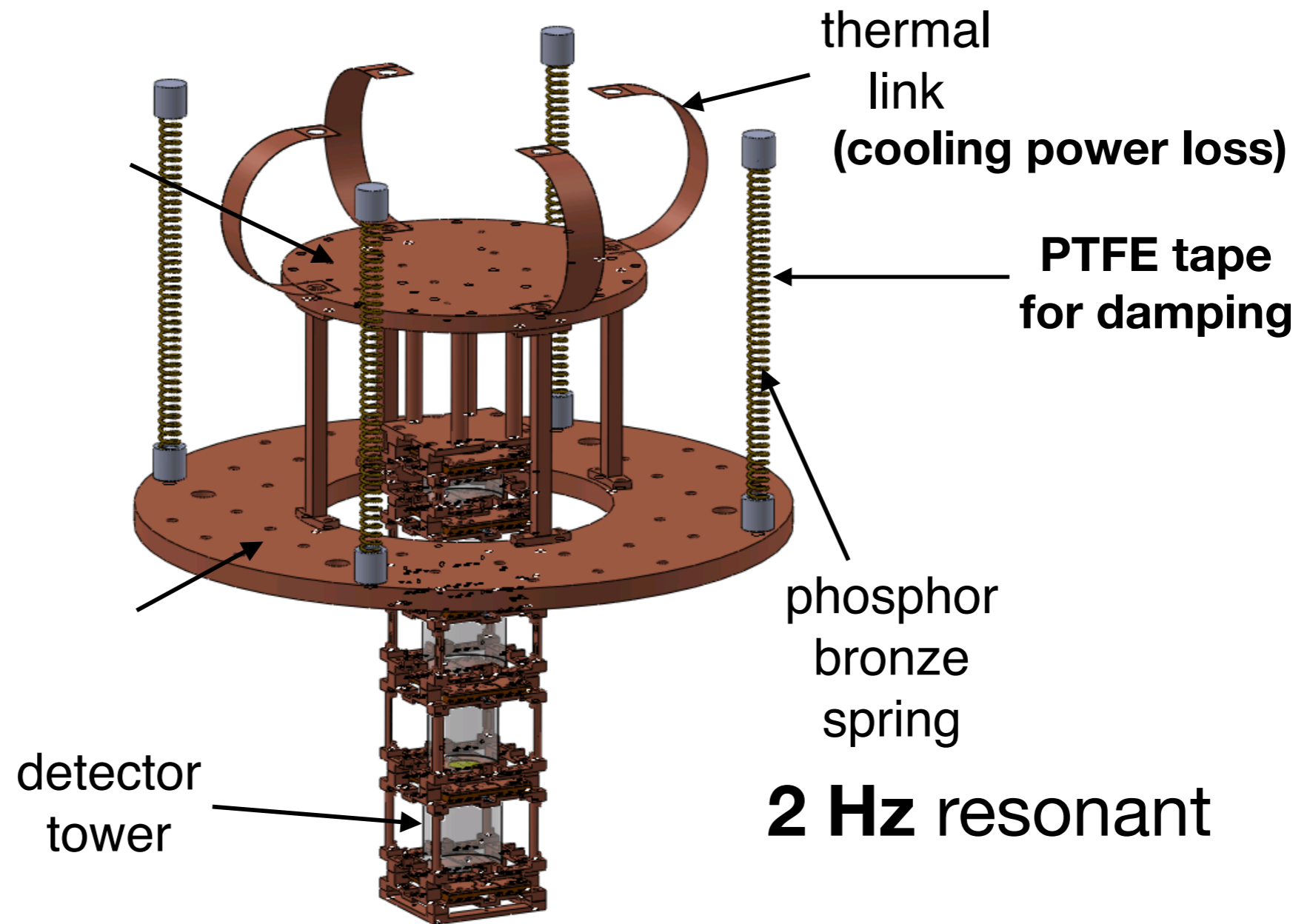
Geophone on **still plate**
 Temperature: ~4K

vertical a_{rms} reduced by 3.9

rms mm/sec ² (1-1000 Hz)	horizontal	vertical
rigid	5.6	21
SSS @ 4K	N/A	5.4
PTR off	0.6	0.6

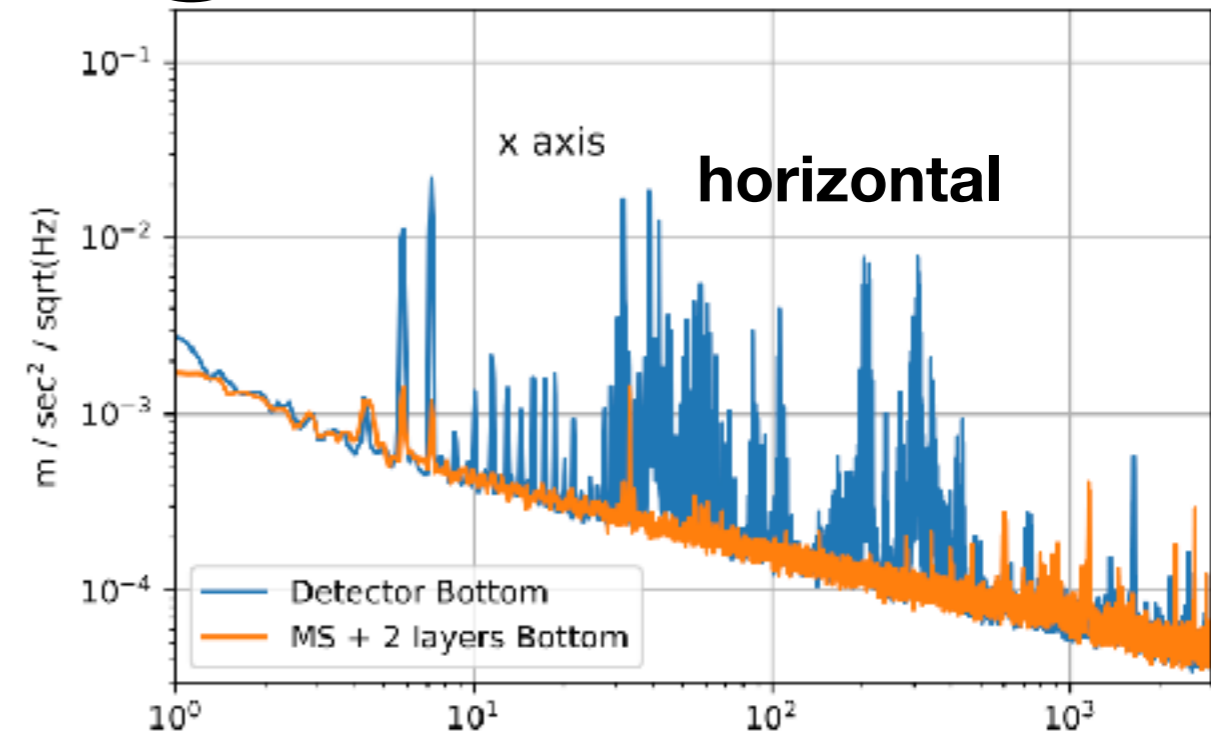
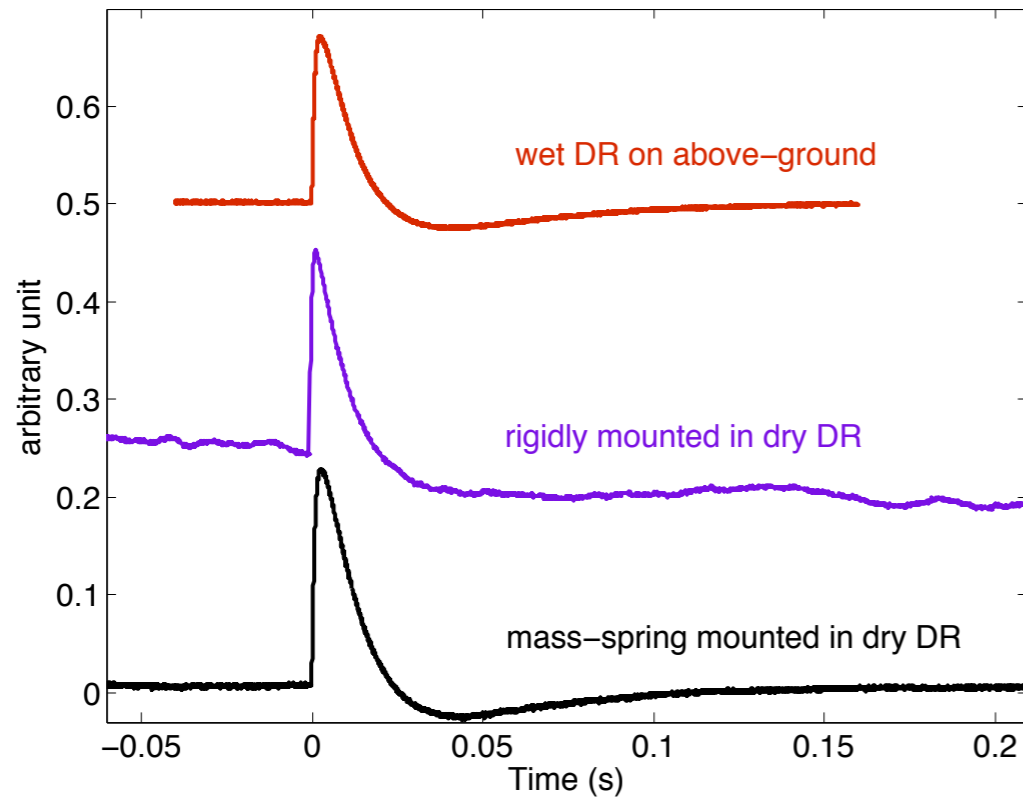


Mass-spring system

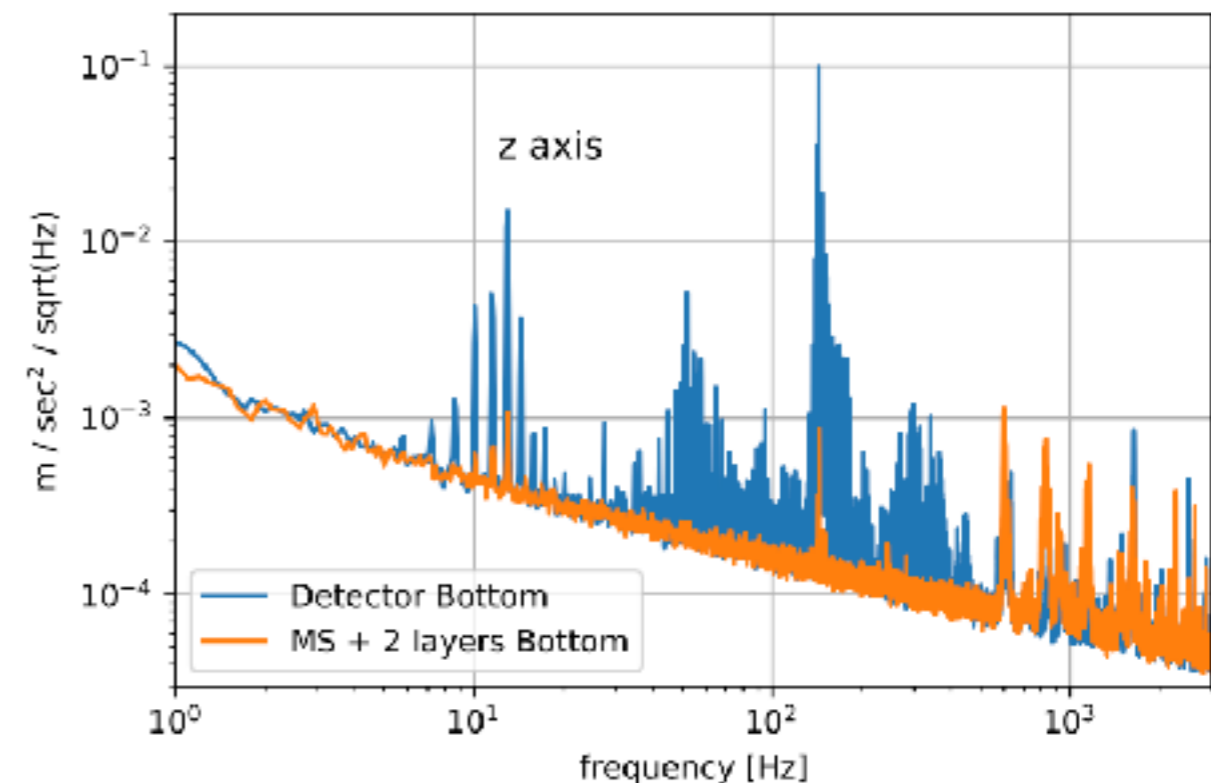


J. Inst 12 (2017) C02057

Mass-spring results

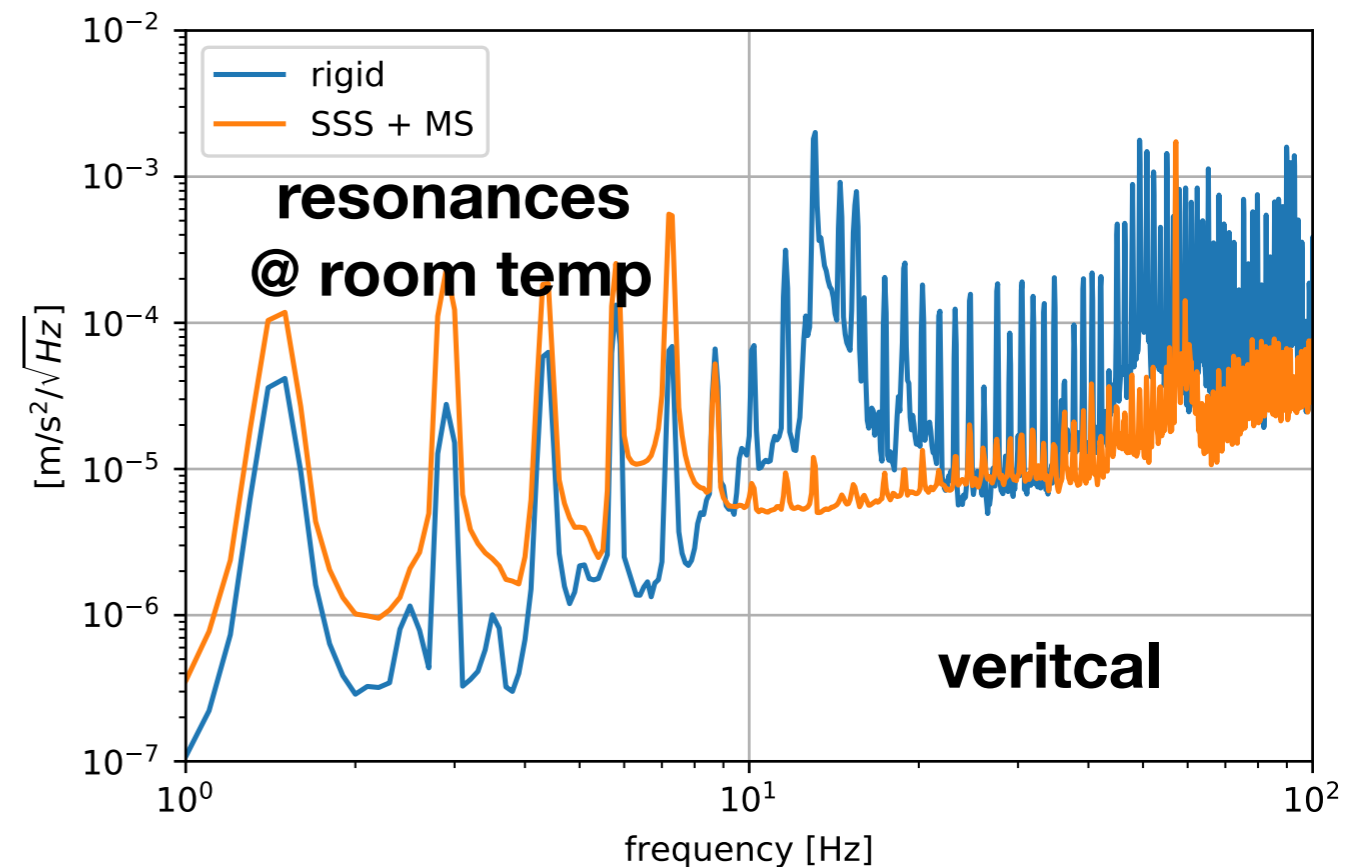
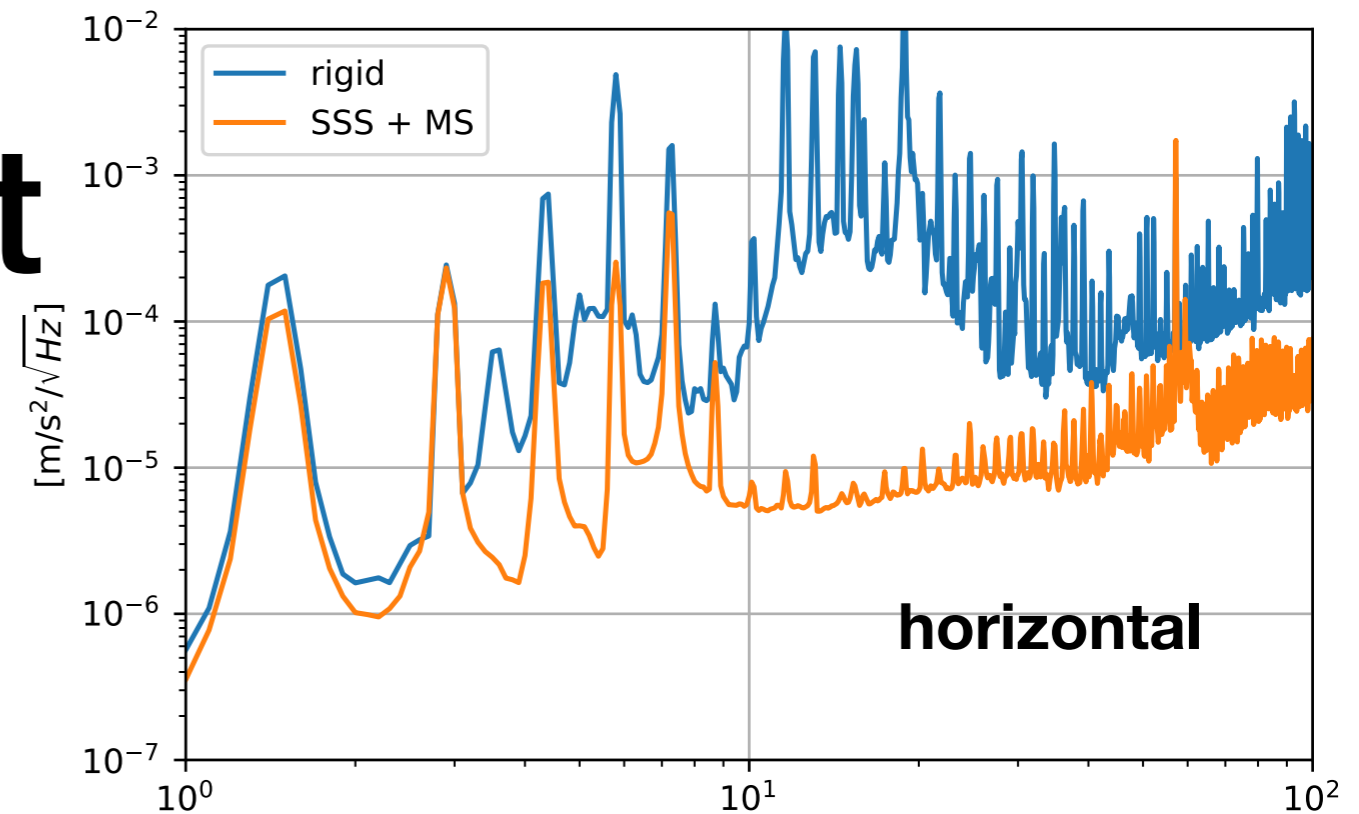


rms mm/sec^2 (1-3000 Hz)	horizontal		vertical	
	horizontal	vertical	horizontal	vertical
rigid	20	47		
Mass-spring	5	7		
PTR off	5	5		



Results for AMoRE-pilot

- Laser-interferometer @ detector tower bottom

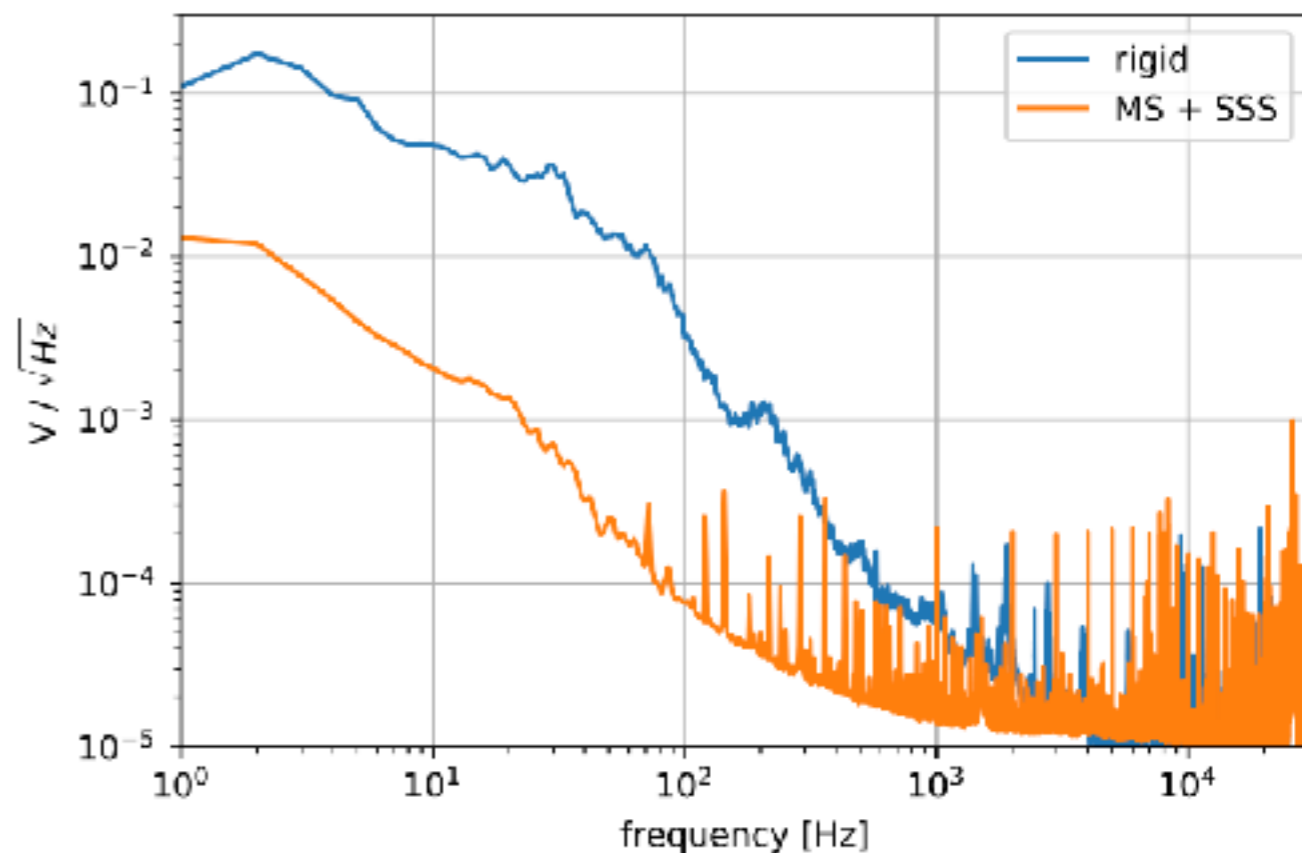
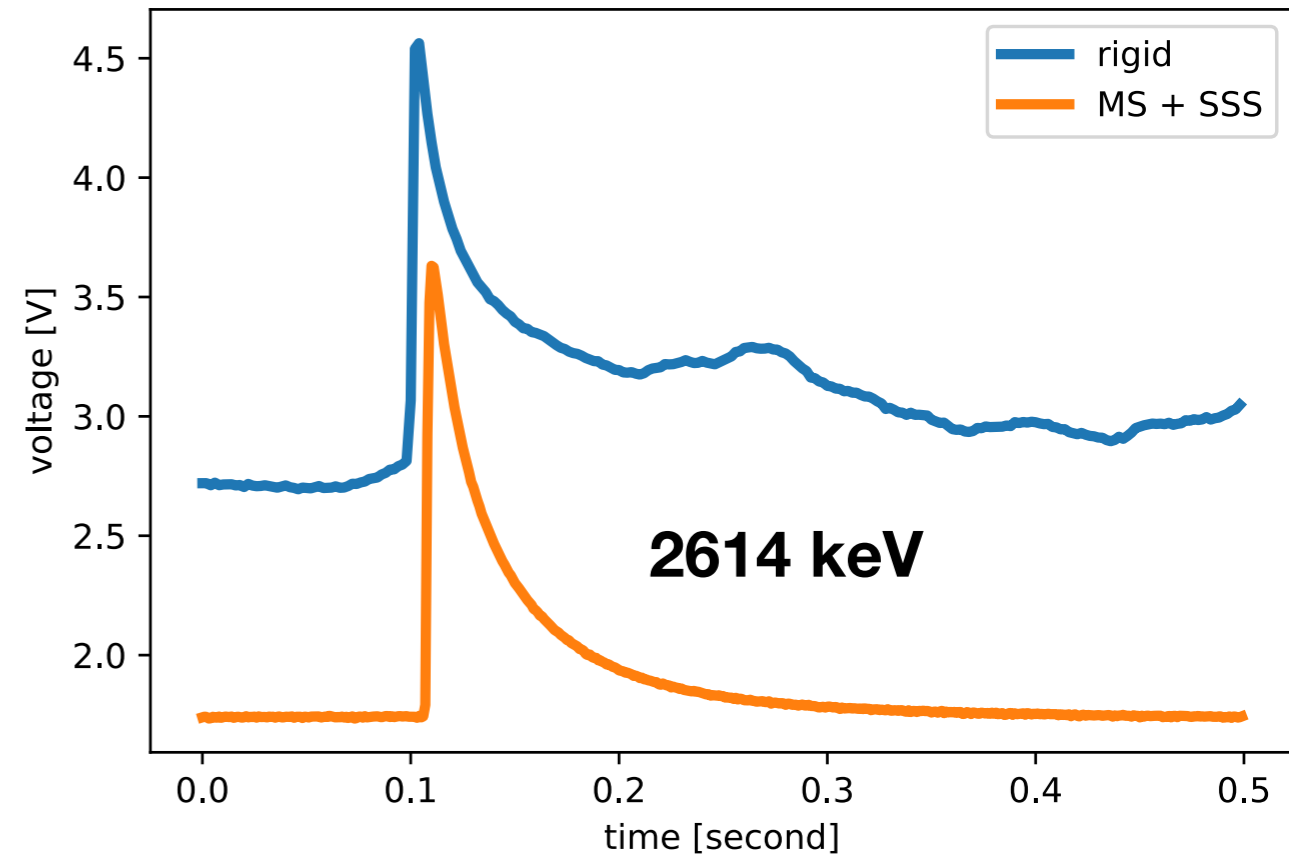


rms mm/sec ² (DC-100 Hz)	horizontal	vertical
rigid	13	2.5
SSS + MS	1.2	< 0.9
off	0.3	0.1

MMC Signal improvement

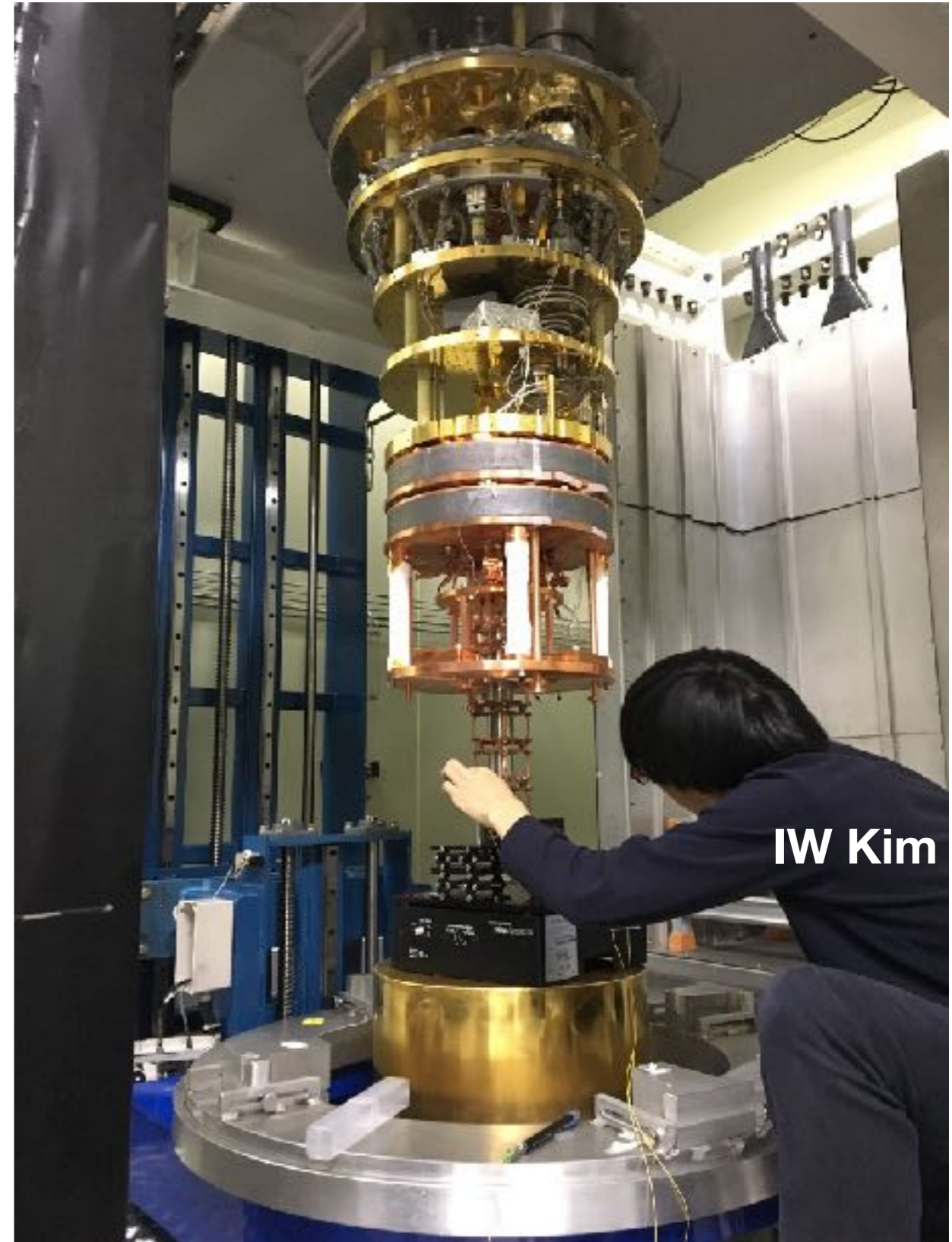
SE01 crystal	Original	SSS + mass-spring
V_{rms} (DC-10kHz)	0.37 V	0.023 V
baseline resolution	20 keV	3 keV
Energy resolution @ 2614 keV	24 keV	8.7 keV

Check Poster PE-31



Summary & discussion

- Vibration in AMoRE-pilot cryogen-free dilution refrigerator was **measured**.
 - Major acceleration peak in 10-300 Hz
- The mechanical filters effectively **isolated the vibration**.
- The performance of the detectors improved significantly.
- Residual vibration: lowest frequencies, vertical internal modes



BACKUP slides

References

- Spring for wet DR
S. Pirro et al, Nucl. Instrum. Meth. A 444 (2000) 331.
S. Pirro, Nucl. Instrum. Meth. A 559 (2006) 672.
- Microscopy
den Haan et al., Rev. Sci. Instrum. 85 (2014) 035112
Pelliccione et al., Rev. Sci. Instrum. 84 (2014) 033703

Leiden Univ. Example

- SSS
- PTR decouple & external support
- Rigid support

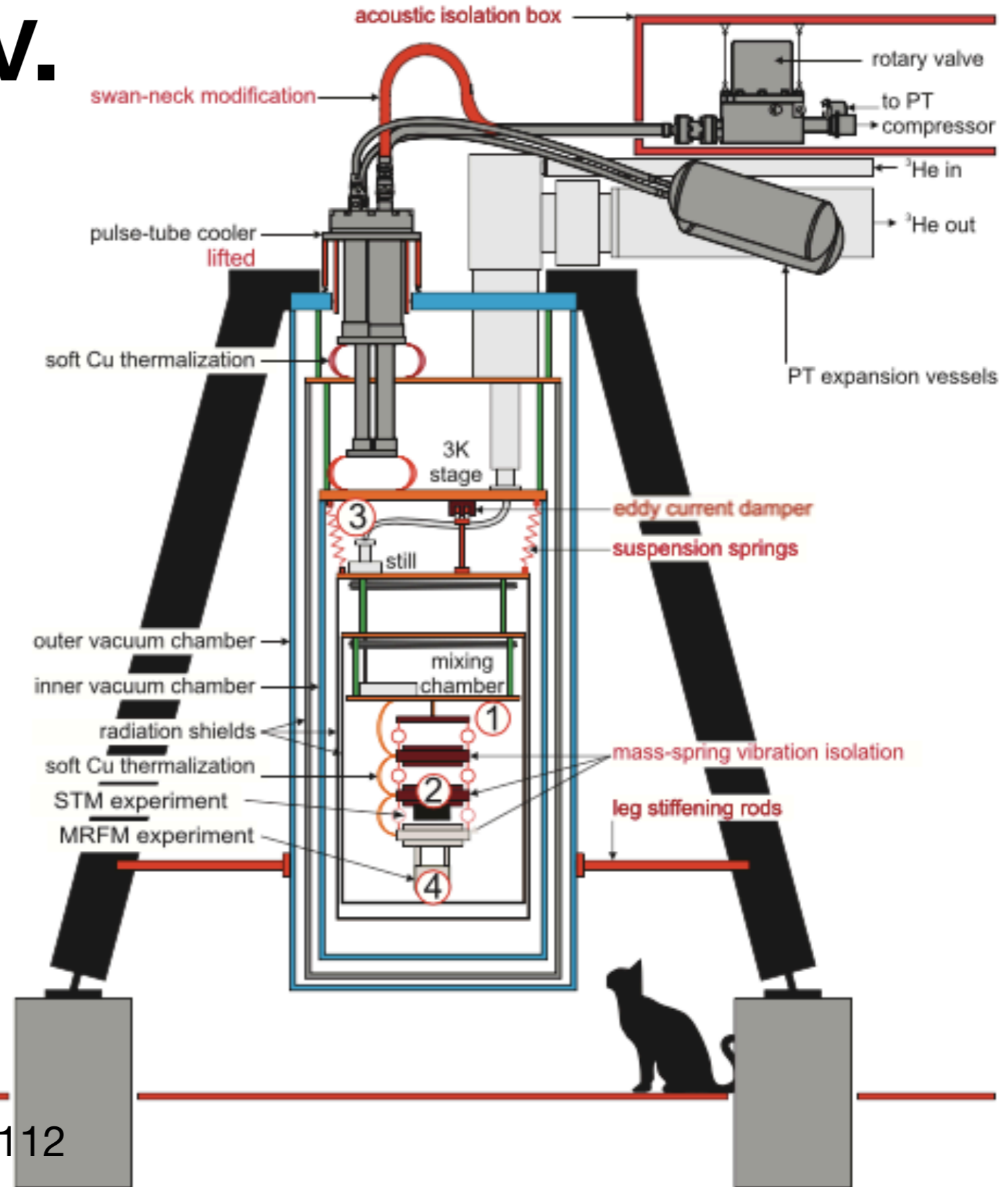


Figure from den Haan et al.,
Rev. Sci. Instrum. 85 (2014) 035112

SSS transfer functions

