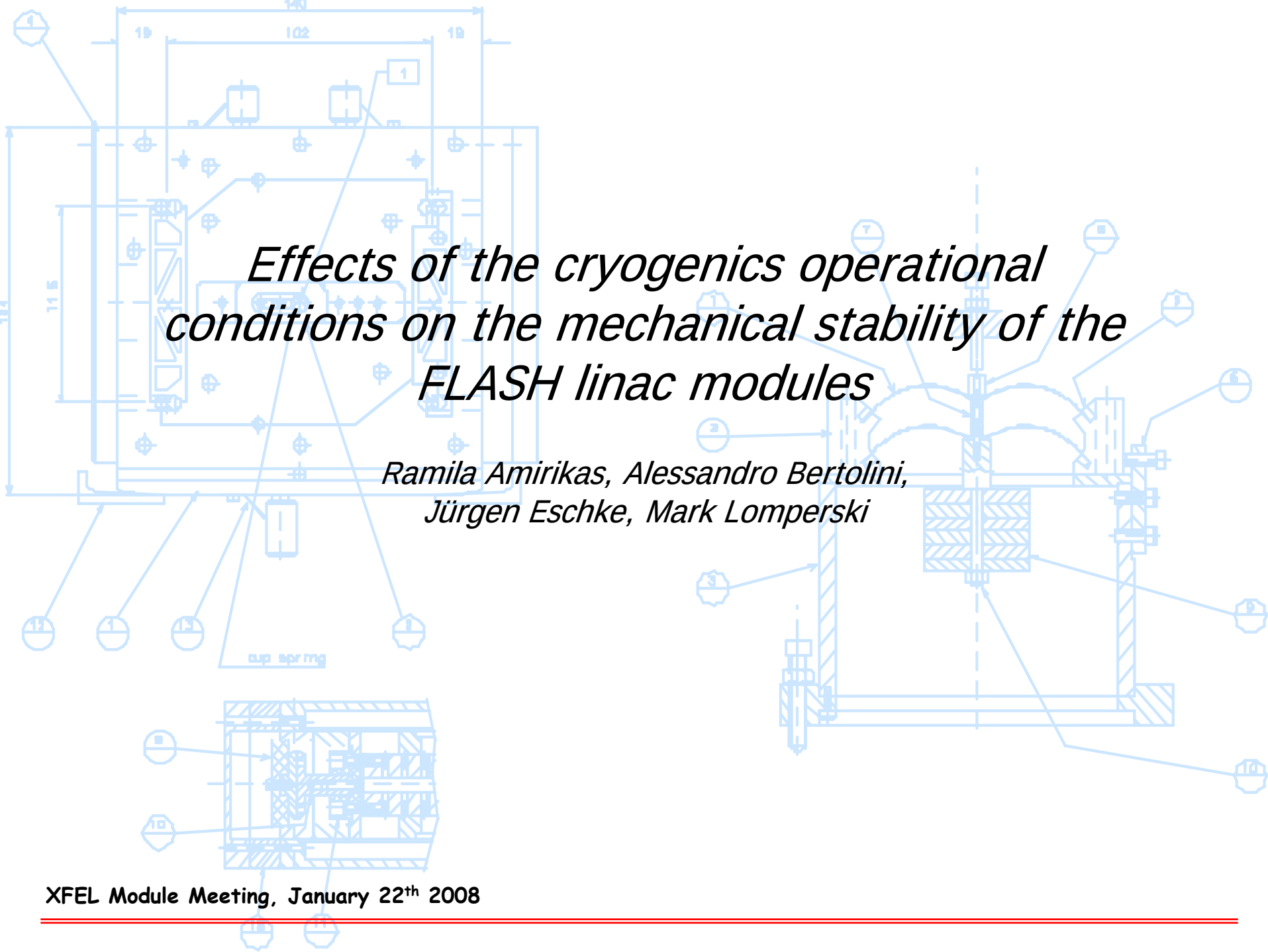


Effects of the cryogenics operational conditions on the mechanical stability of the FLASH linac modules

Ramila Amirikas, Alessandro Bertolini,
Jürgen Eschke, Mark Lomperski

XFEL Module Meeting, January 22th 2008

Introduction
- summary of the CMTB results on ACC5 and ACC6

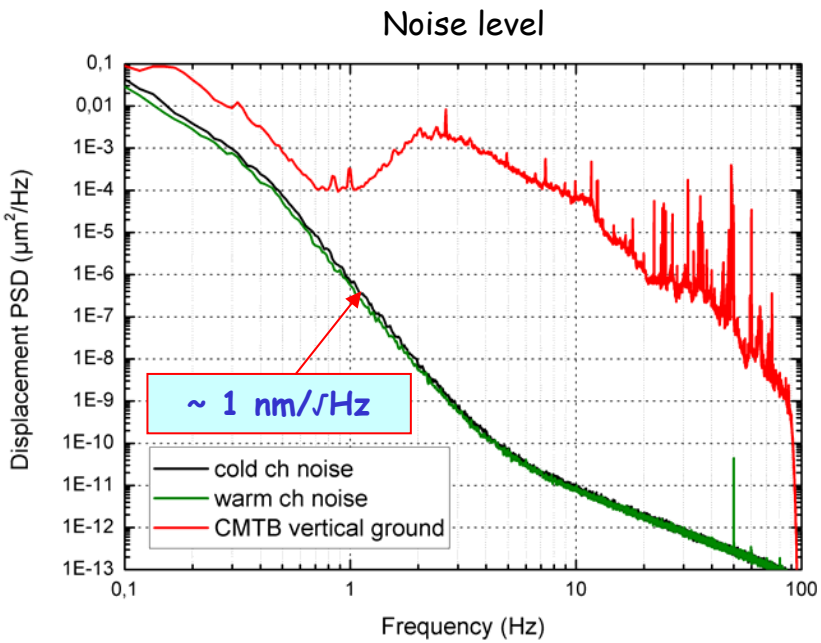
FLASH monitoring system
- motivation
- hardware
- software

Effects of cryogenics (Jürgen)
- geophones on DOOCS
- tests on the 70K shield
- tests on the 4.5K shield
- spectral analysis (Alessandro)

Vibrations of cavities
- spectra from piezo tuners and comparison with geophones
- the case of ACC6 cavity 1

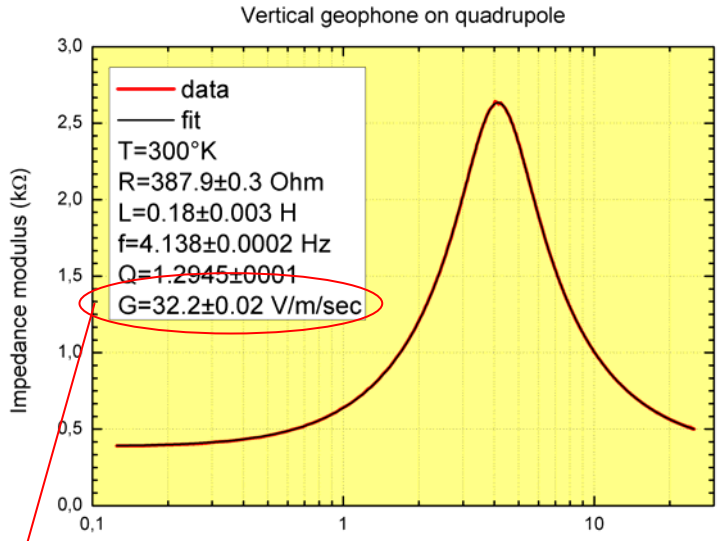
Conclusions and next experiments
- geophone usable for microphonics control?

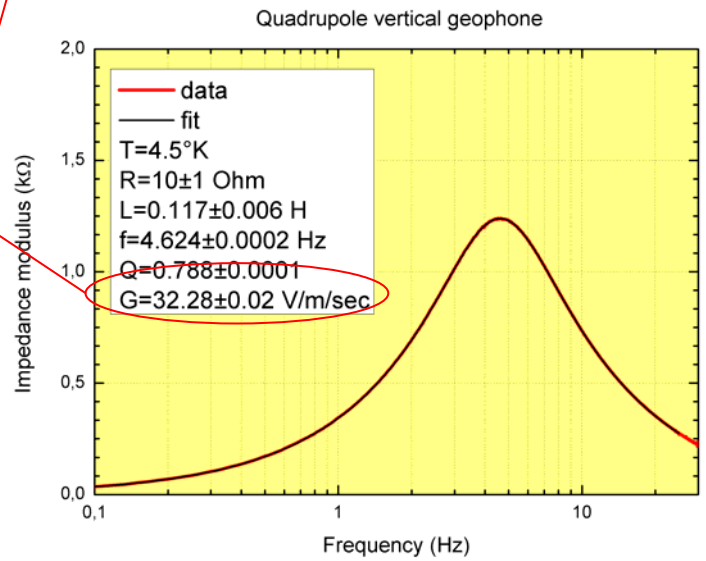
Commercial geophones have shown nanometer level resolution from 1 Hz even at liquid He temperatures and remote calibration capability

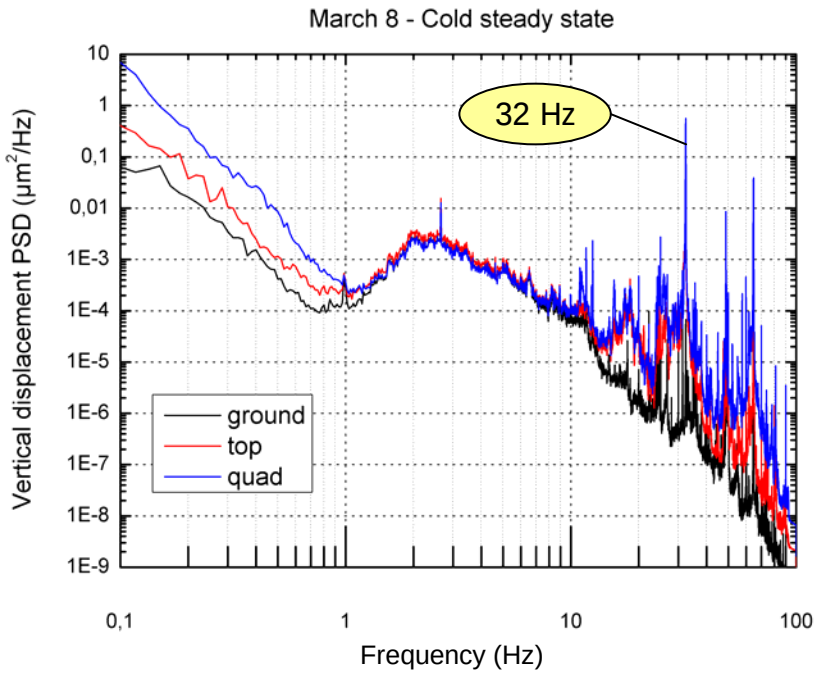


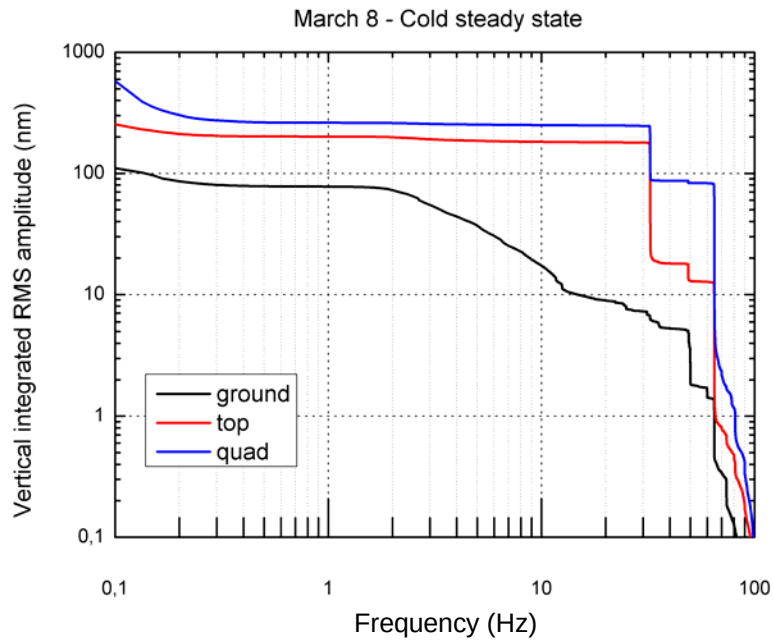
Oyo Geospace GS11D

No loss of sensitivity at liquid helium temperature !!







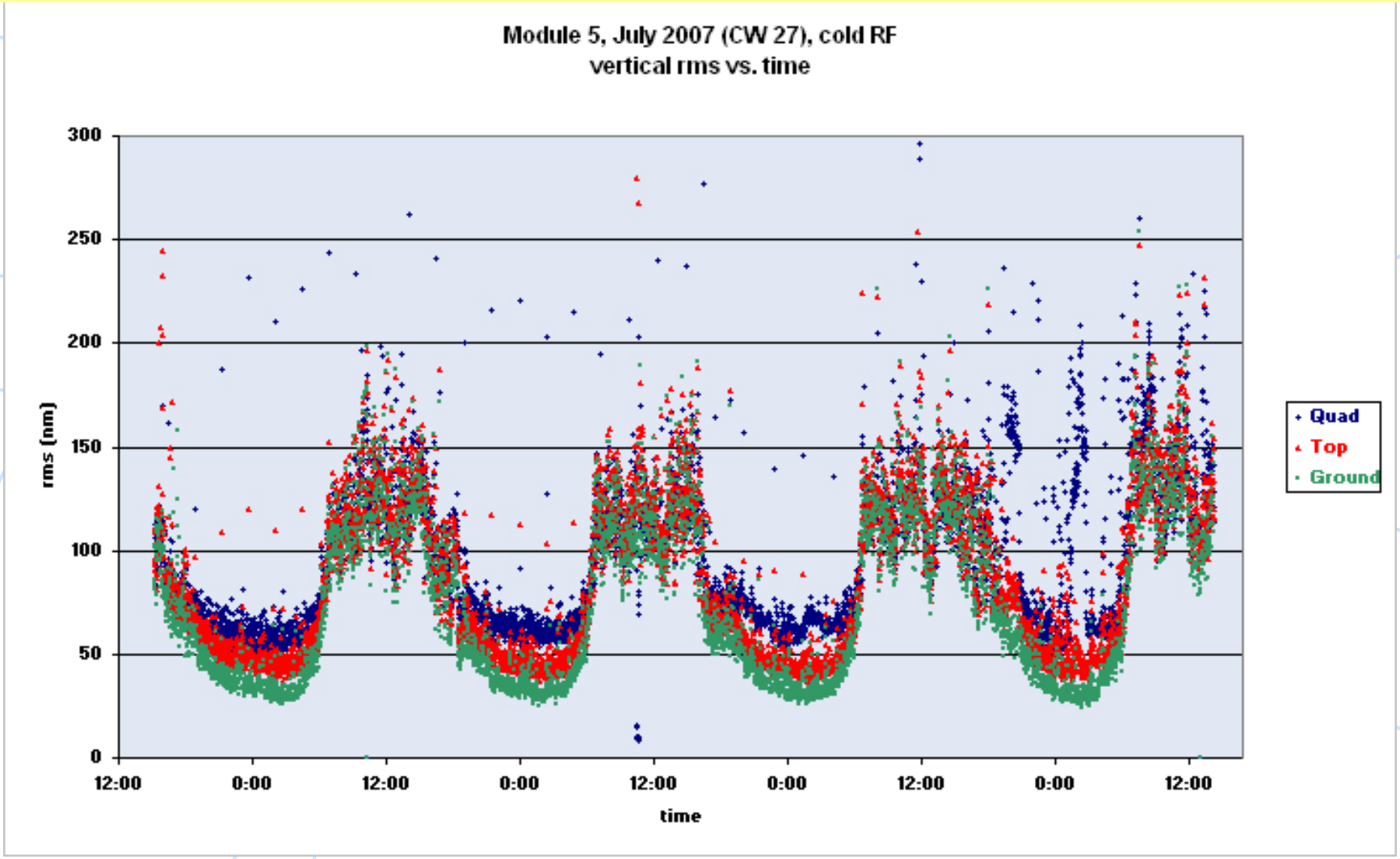


- **low frequency (1-100 Hz) quadrupole vertical stability not affected by high gradient RF operation**

- **quadrupole vertical stability not affected by the refrigeration system at frequencies up to 30 Hz; results not conclusive at higher frequency because of the onset of a thermal acoustic oscillation in a diagnostic pipe upward of the 4.5K LHe forward line.**

- **high level of vibrations (up to 600 nm RMS) correlated with the parameters of the 4.5K line**

Good results on ACC5 with very quiet operation during the whole test. No effect from the refrigeration system was observed. Quad motion dominated by ground motion (see night and day trend).



The experiment - continuous monitoring of vibrations in the string of three Type III cryomodules + ACC3 during normal machine operation.

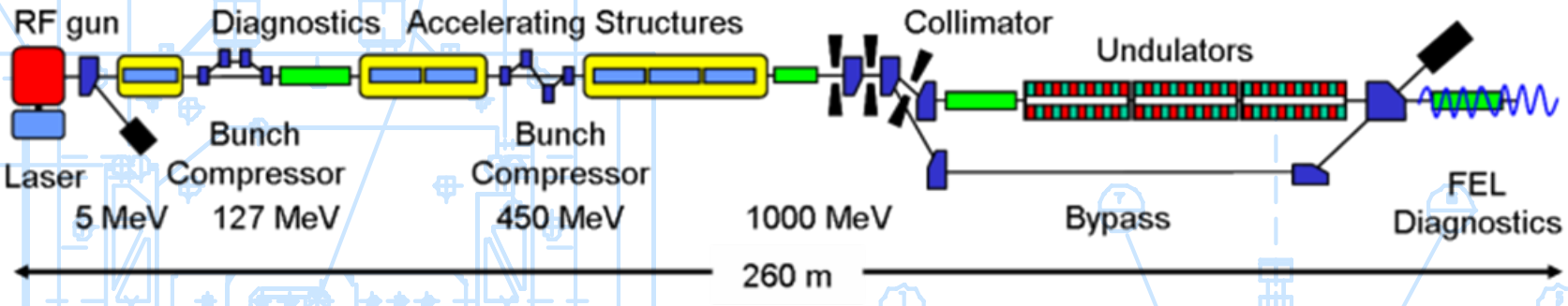
Goals

• evaluate the impact of the cryogenic plant on the mechanical dynamic stability of the linac, and compare it to the other sources of vibrations (ground motion, insulation vacuum system, etc.)

• study possible vibrations induced on quadrupoles (and cavities) by the 4.5K and 70K shields

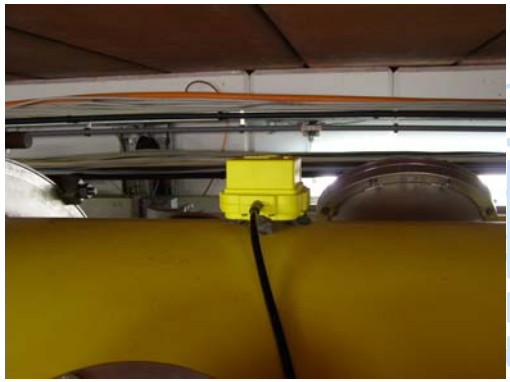
• quantitative measurement/ correlation of high level `microphonics` on the stability of the cavities

• quantitative measurement of the correlated motion between adjacent quadrupoles at both XFEL and ILC-like quad distance, for beam dynamics studies

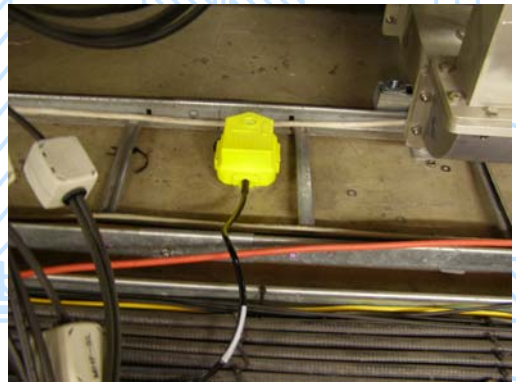


*The string of three Type III cryomodules (ACC4,5,6) has been instrumented with inertial velocity sensors (Oyo Geospace GS11D geophones). Each quadrupole is equipped with a single axis vertical sensor (even horizontal but they are not working, replacement from Sensor BV going to be tested soon); a triaxial geophone is placed on top of the main vessel (quad side) of each cryomodule. A further triaxial sensor is placed, as a reference, on the tunnel floor underneath ACC5.

Geophones on the quad He vessel

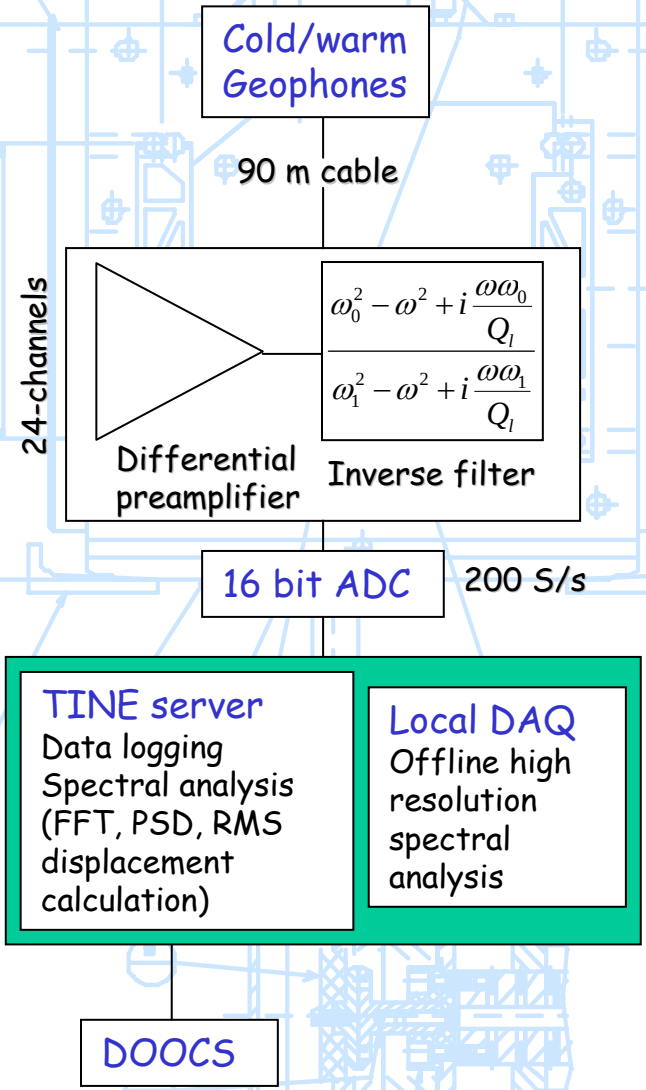


Triaxial sensor on vessel top



Reference sensor on tunnel floor

*ACC3 (Type II) is also similarly instrumented for correlated motion studies at ILC-like quad distance.



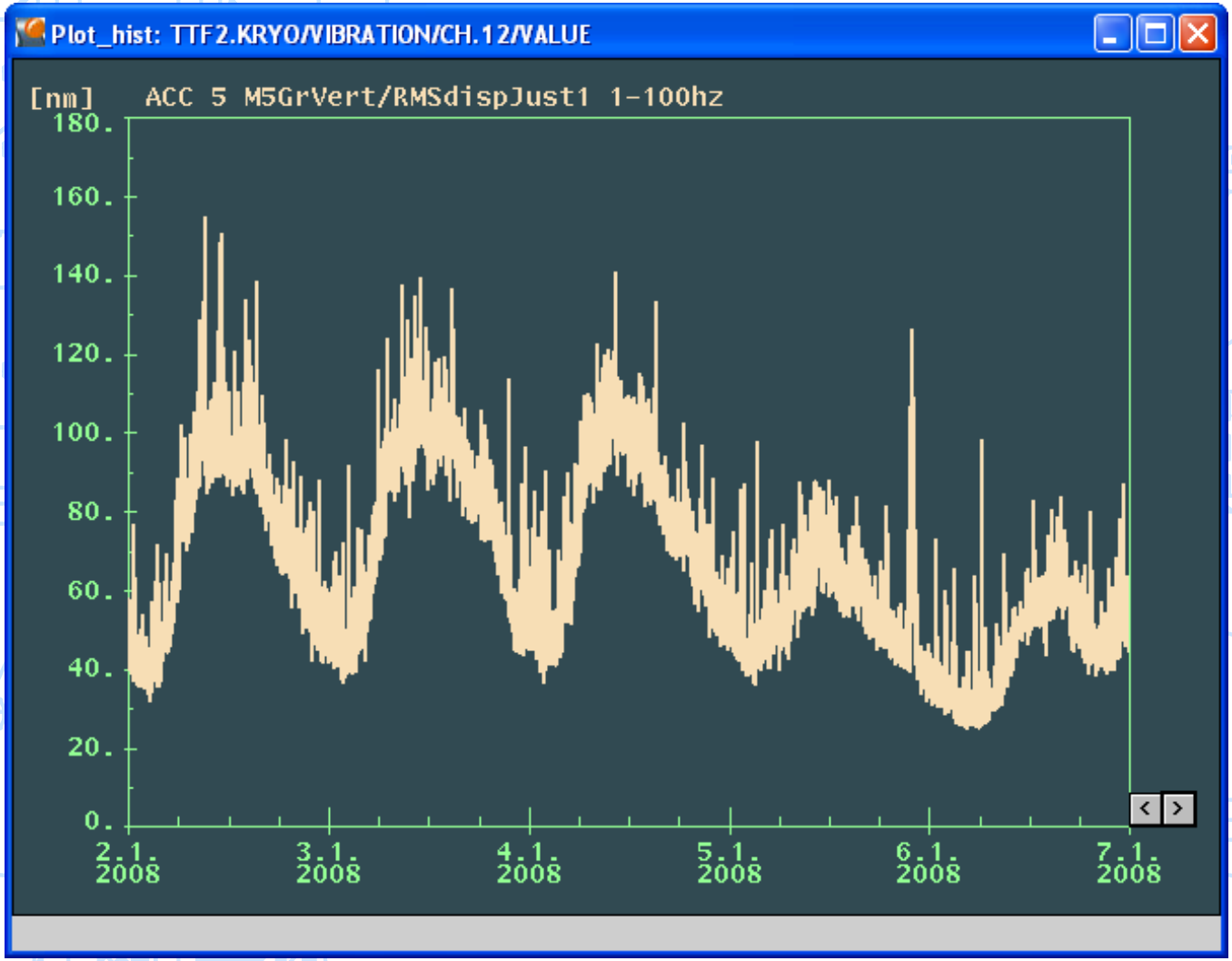
Some definitions

$x(t)$, $y(t)$	velocity time series of length T, N points each
$X(\nu_i)$, $Y(\nu_i)$	FFT
$\frac{XX^*}{(2\pi\nu_i)^2}$, $\frac{YY^*}{(2\pi\nu_i)^2}$	displacement power spectral density
$\sqrt{\frac{1}{T}\sum_{i=k}^{m} XX^*/(2\pi\nu_i)^2}$	RMS displacement in the frequency band (ν_k , ν_m)
$\frac{Re\{<XY^*>\}}{\sqrt{<XX^*><YY^*>}}$	correlation

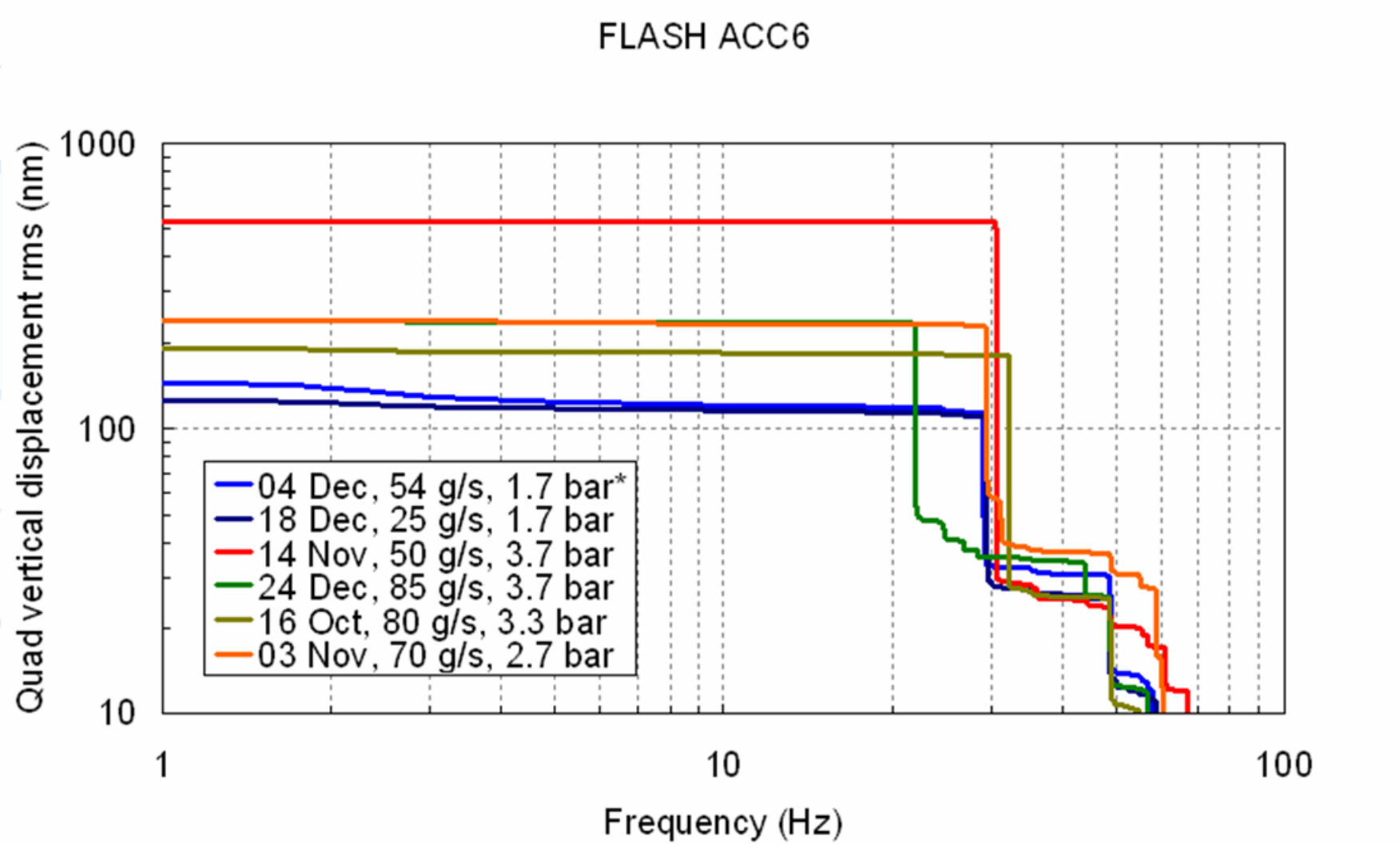
What you see in the DOOCS display

the RMS displacement, integrated over the 1-100 Hz and 20-40 Hz frequency bands, measured during the last 20.5 sec, updated every ~1 second

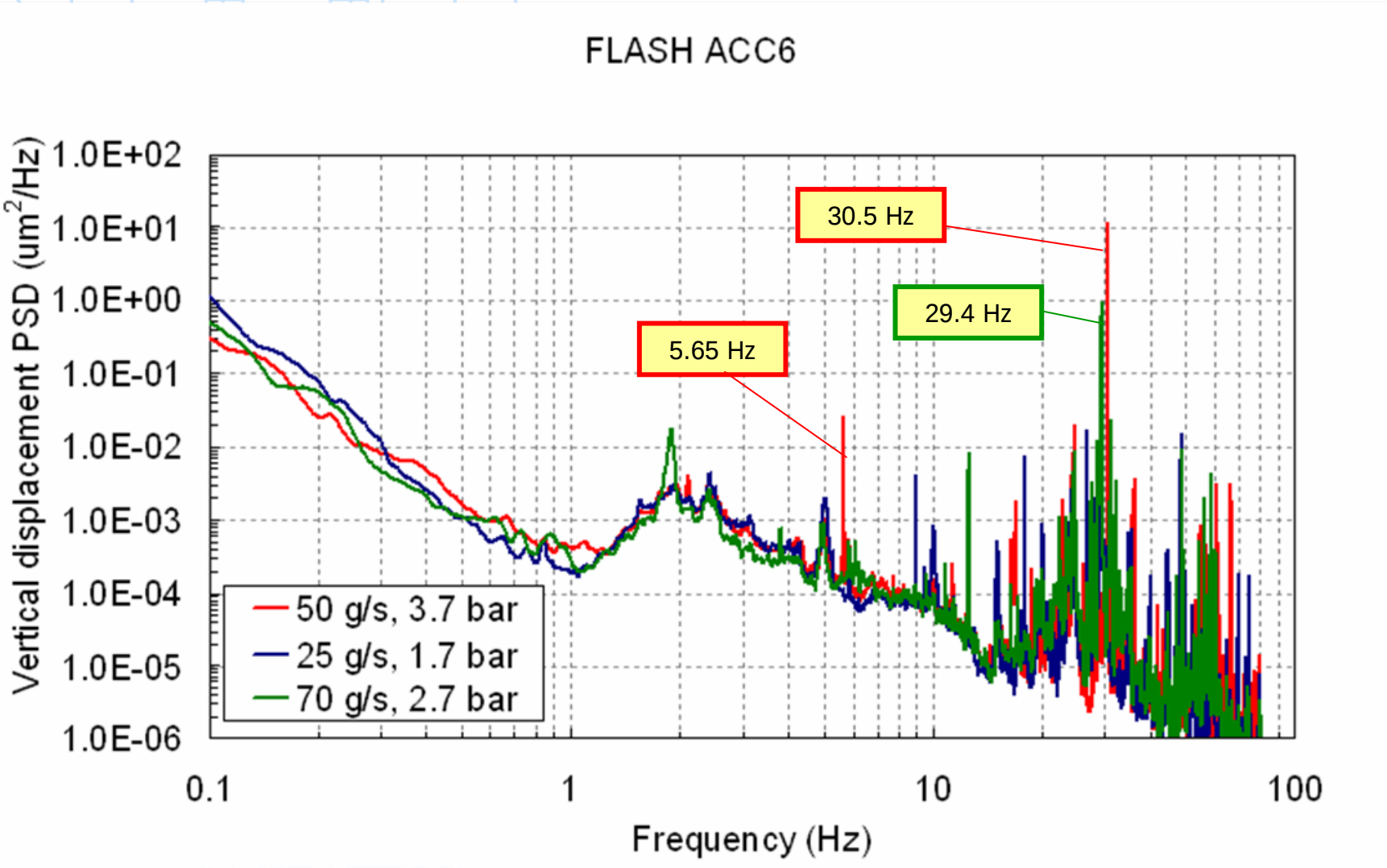
Vertical ground motion history (ACC5)

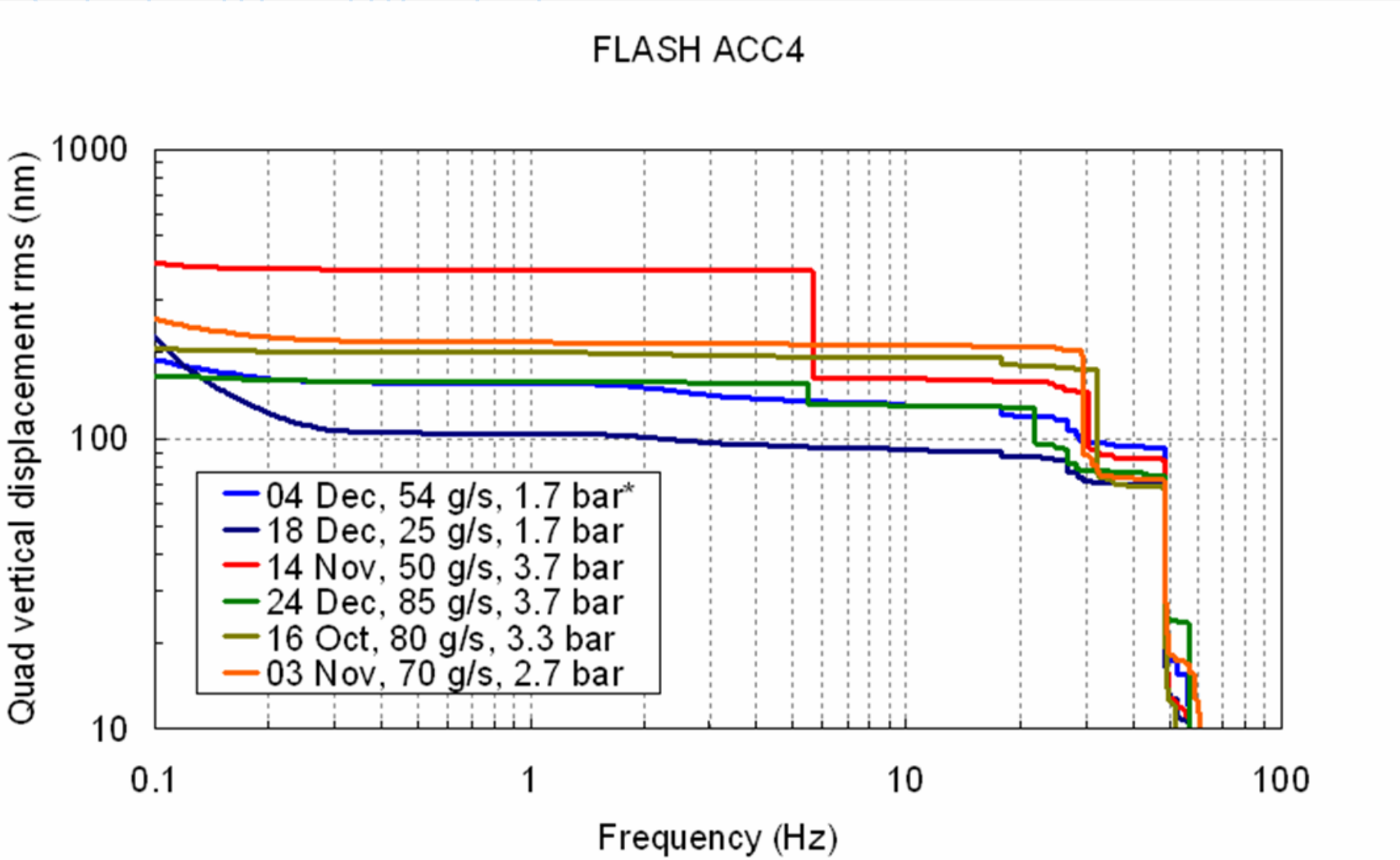


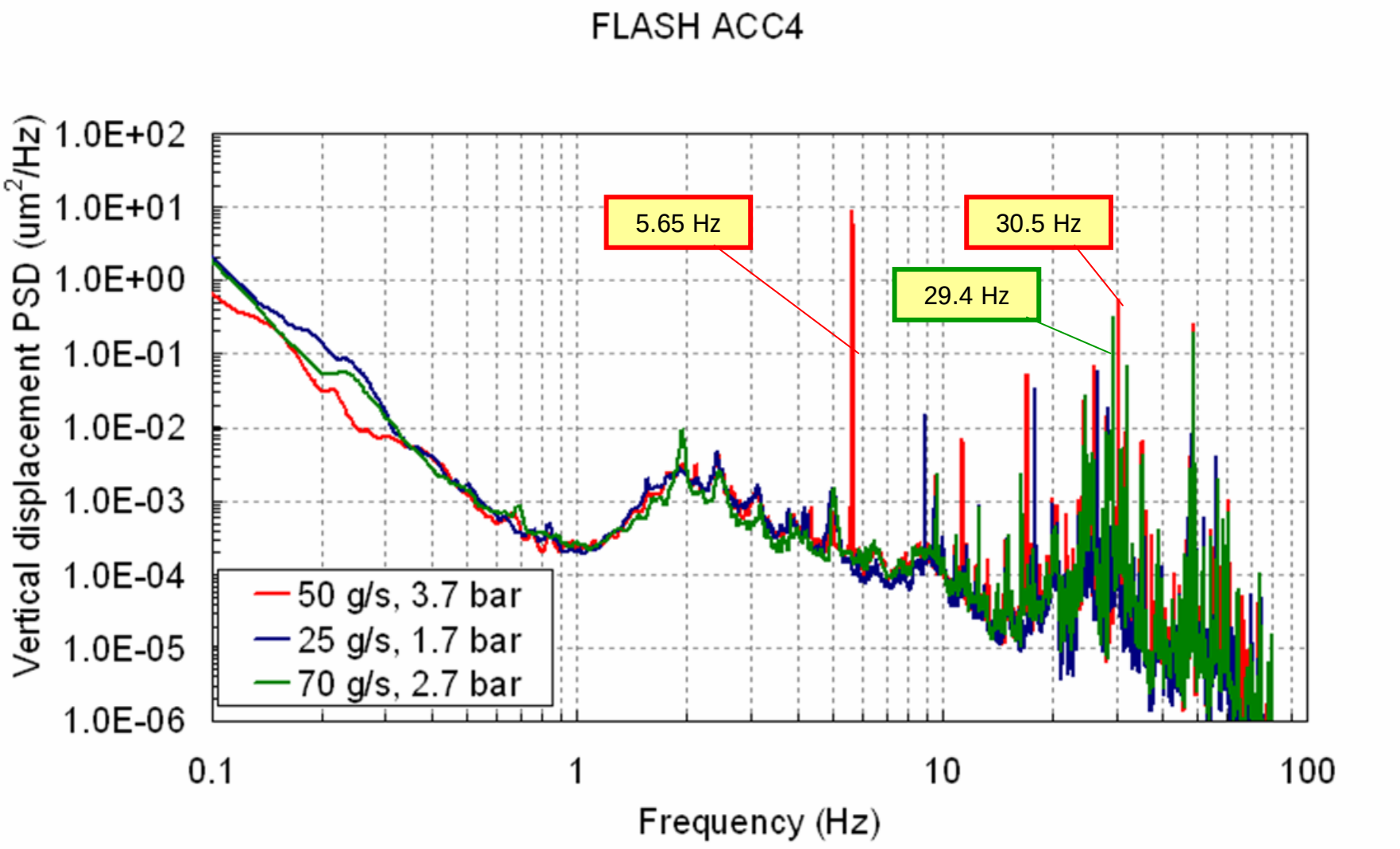
Lowest vibration amplitude `thinkable` for the quadrupoles in the FLASH linac

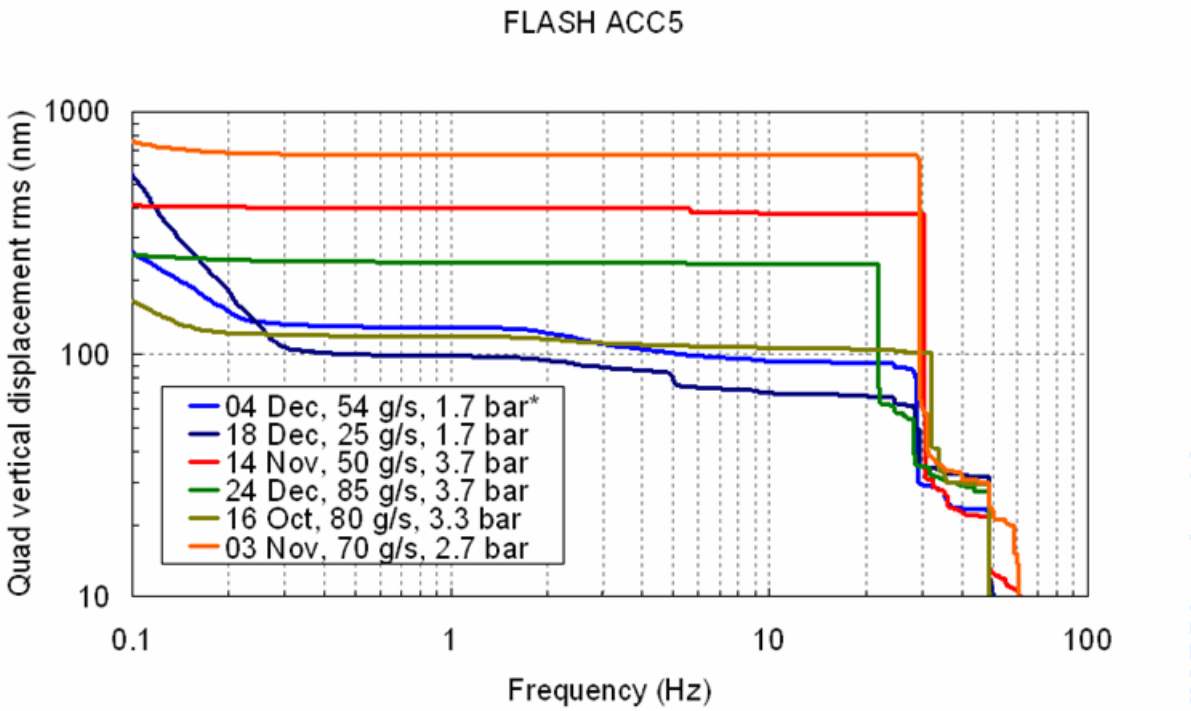


Average over 4 hrs during the night (except for 4-12-2007 from 4 to 9 PM)


FLASH ACC6
Vertical displacement PSD (um²/Hz)
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
0.1
1
10
100
Frequency (Hz)
30.5 Hz
29.4 Hz
5.65 Hz
50 g/s, 3.7 bar
25 g/s, 1.7 bar
70 g/s, 2.7 bar


FLASH ACC4
Quad vertical displacement rms (nm)
1000
100
10
0.1
1
10
100
Frequency (Hz)
04 Dec, 54 g/s, 1.7 bar*
18 Dec, 25 g/s, 1.7 bar
14 Nov, 50 g/s, 3.7 bar
24 Dec, 85 g/s, 3.7 bar
16 Oct, 80 g/s, 3.3 bar
03 Nov, 70 g/s, 2.7 bar


FLASH ACC4
Vertical displacement PSD (um²/Hz)
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
0.1
1
10
100
Frequency (Hz)
5.65 Hz
30.5 Hz
29.4 Hz
50 g/s, 3.7 bar
25 g/s, 1.7 bar
70 g/s, 2.7 bar



General comments

Three typical behaviour observed as a function of the pressure:
- Low pressure (1.5-1.7 bar) -> low noise
- Intermediate pressure (2.7-3.3 bar) -> appearance of a strong line around 30 Hz
- High pressure (3.7 bar) -> ~30 Hz line plus a low frequency line around 6 Hz

No systematic dependence on the flow.

Disturbances have the same frequencies along the whole linac.

Vibration transfer from quad to the cavity string?

Piezo tuner+dressed cavity (9-cell+He tank + tuner mechanics) works like an accelerometer sensitive along the axis of the cavity.

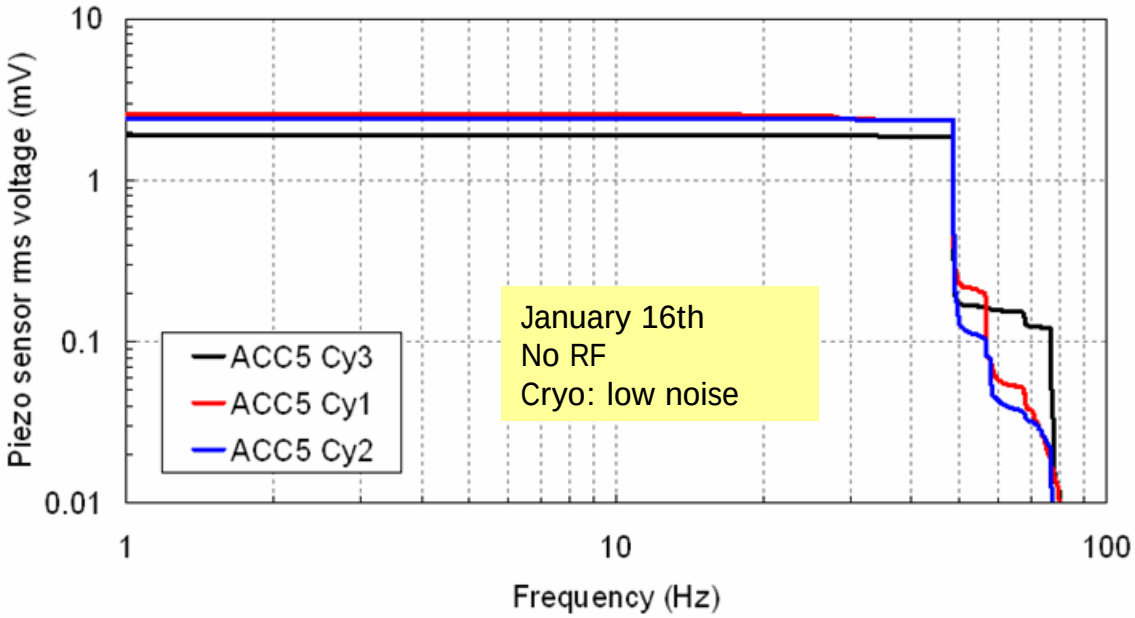
Lack of calibration and different sensitivity between cavities/modules-> only qualitative information.

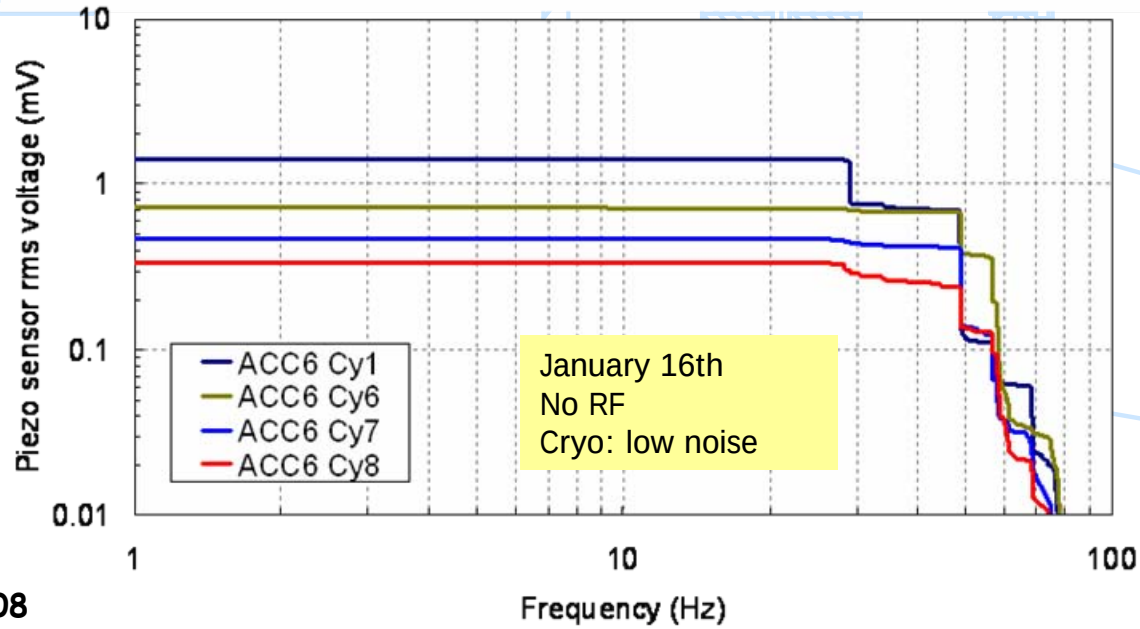
<u>Some features</u>

In ´low noise´operation ACC5 spectrum dominated by the isolation vacuum pump.

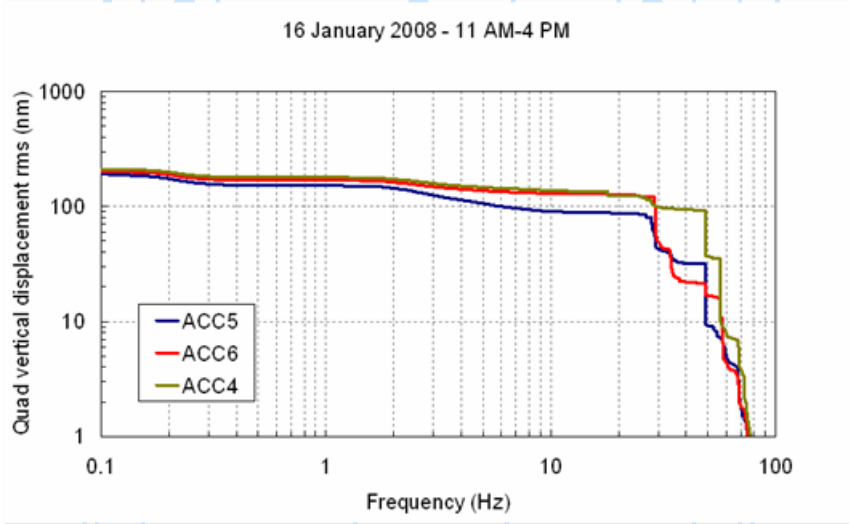
ACC6 shows a more prominent line at 29 Hz.

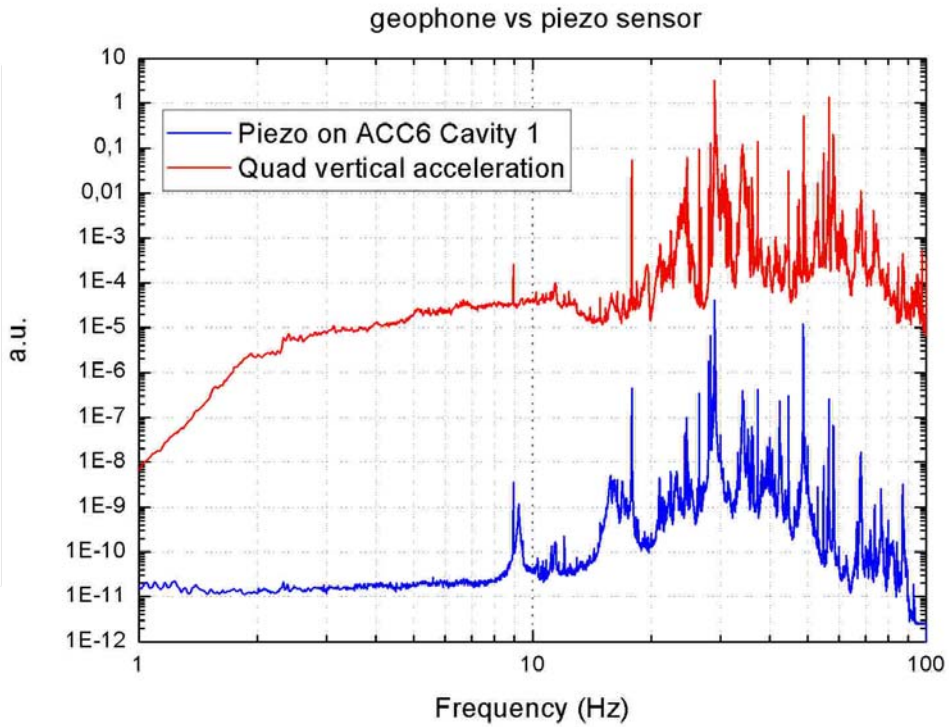
Cavity 1 is systematically the noisiest.





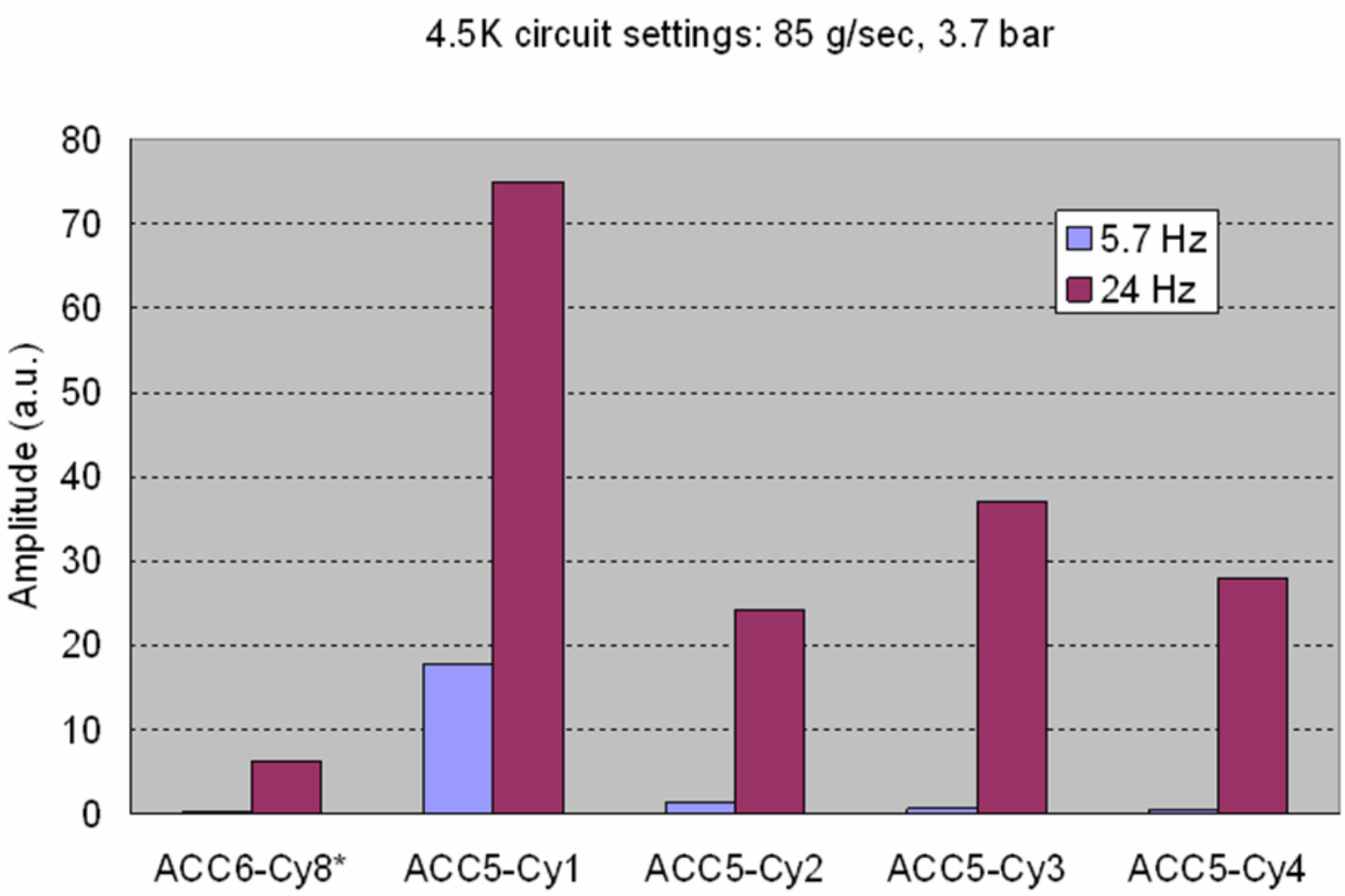
What we mean for 'low noise'



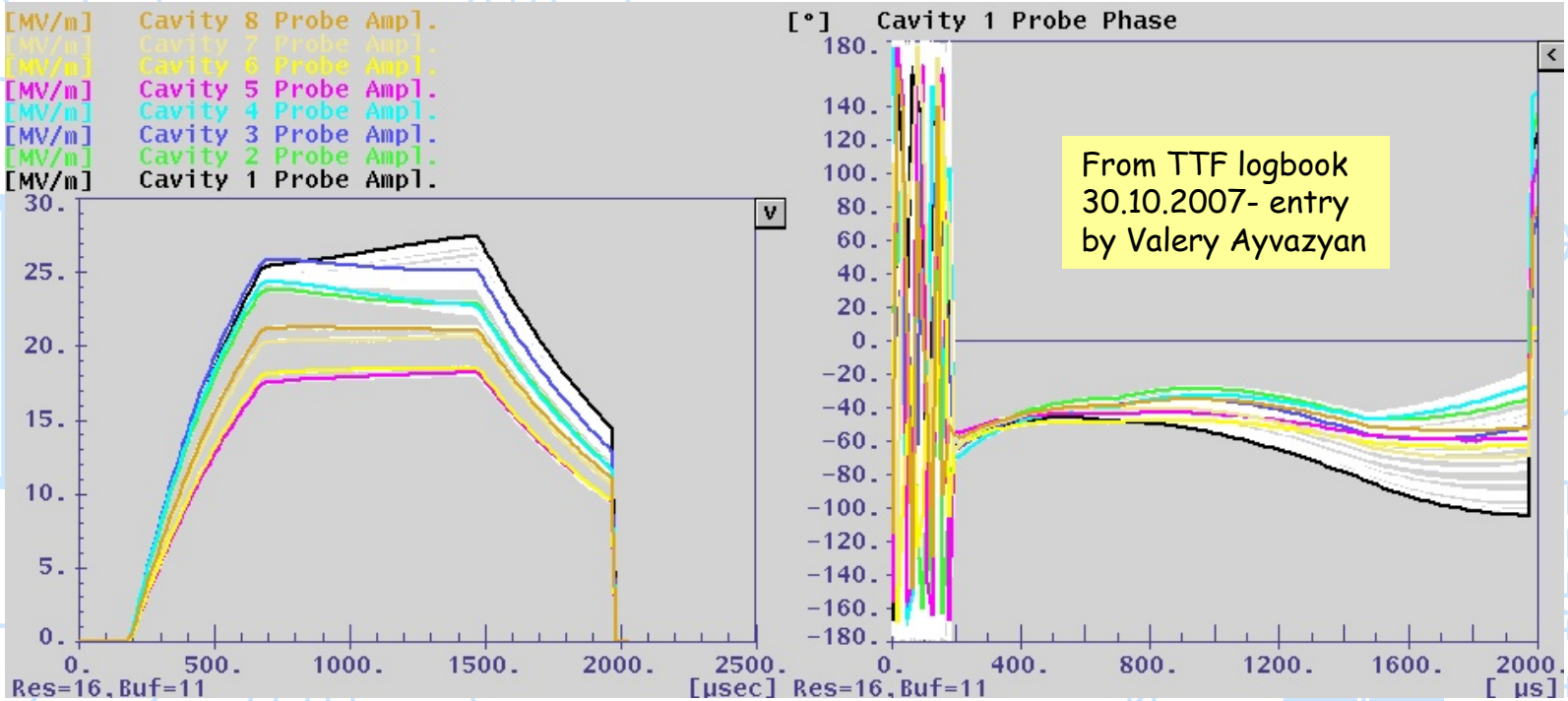


Vertical geophones on the quadrupoles show the same spectral `signature` observed in the cavities with the piezo tuners.

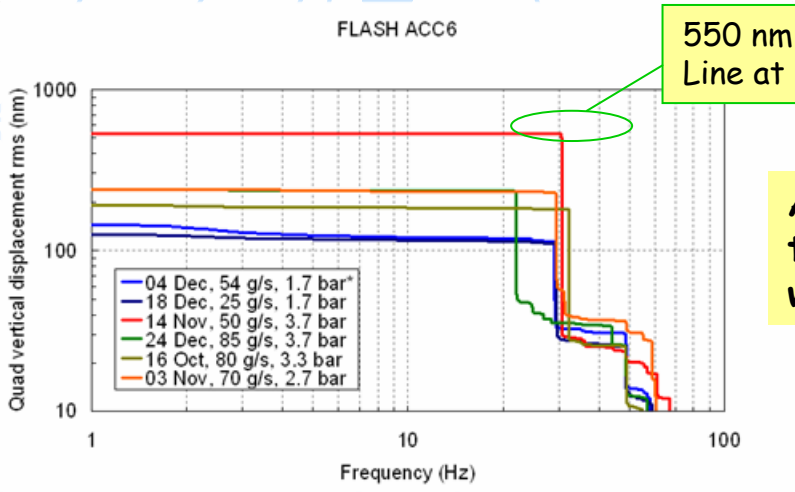
Data of January 11th 2008



Noise tapers off going far from the quadrupole …



From TTF logbook
30.10.2007- entry
by Valery Ayvazyan



550 nm RMS
Line at 30.6 Hz

ACC6 Cavity 1 looks more sensitive to vibrations than the other cavities (no such those effects seen on ACC5 with even larger vibration levels).

Summary

- FLASH monitoring system commissioned successfully
- proven as a very useful tool for the optimization of the cryogenic system operation
- strong influence of the 4.5K circuit settings on the vibration level in the machine
- transfer of vibrations from the quadrupole to the cavity string was observed
- no effect from the 70K shield up to 45 g/s flow (it will be ~140 g/s in the XFEL)
- several operating parameters has been checked; long term lasting vibration levels may be provoked in the machine (useful for evaluation of tolerances: beam stability, SASE)

Coming next

- test of Type-III+ Module 8 on the CMTB at high flows in the 4.5K shield (no connection with the quadrupole which operates at 2K).
- cavity vibration measurement and control with geophones in CHECHIA