# Laser_II project status report – Part I : anti-vibration systems

**S. Leone, A. Moggi, F. Scuri**

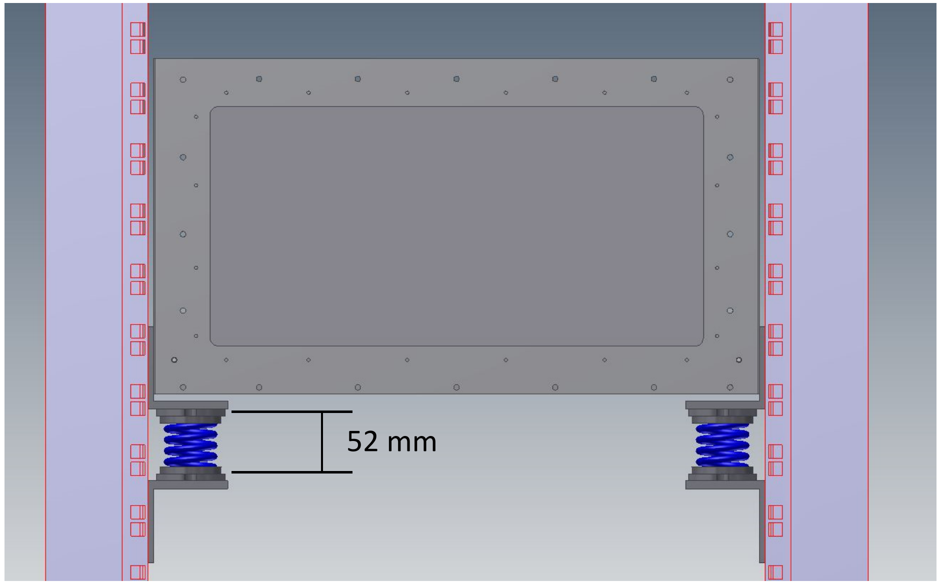
**Atlas/Pisa weekly meeting, June 10, 2014**

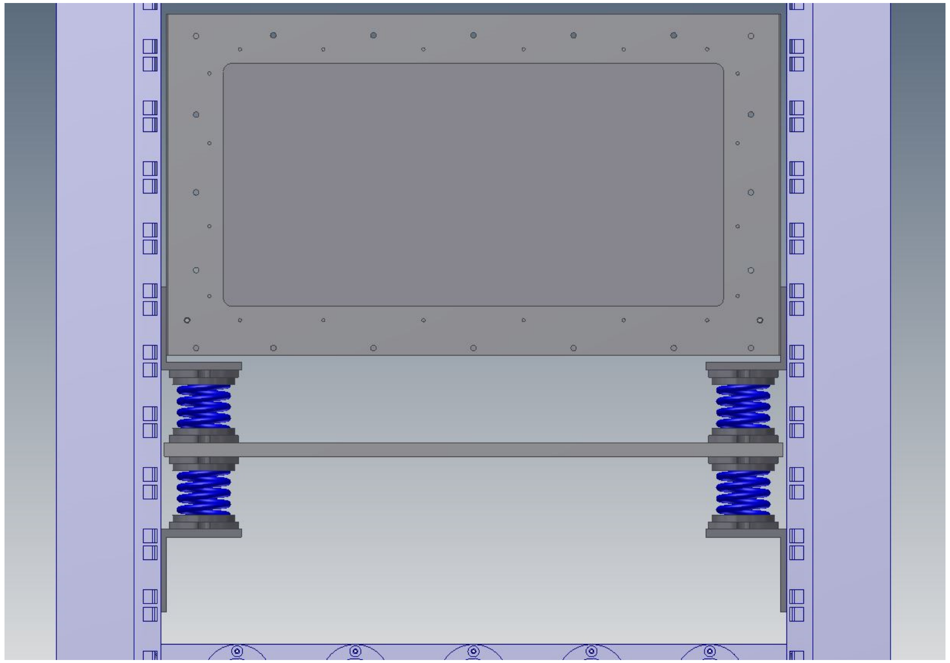
Today : status of the design/construction/test of the anti-vibration system for the optics box

Tuesday June 24, 2014 : status of the qualification of the optical elements inside the box

Tuesday July 1st, 2014 : electronic channel cross-talk studies triggered by Pisa; status of the global project

# The first antivibration system for the optics box



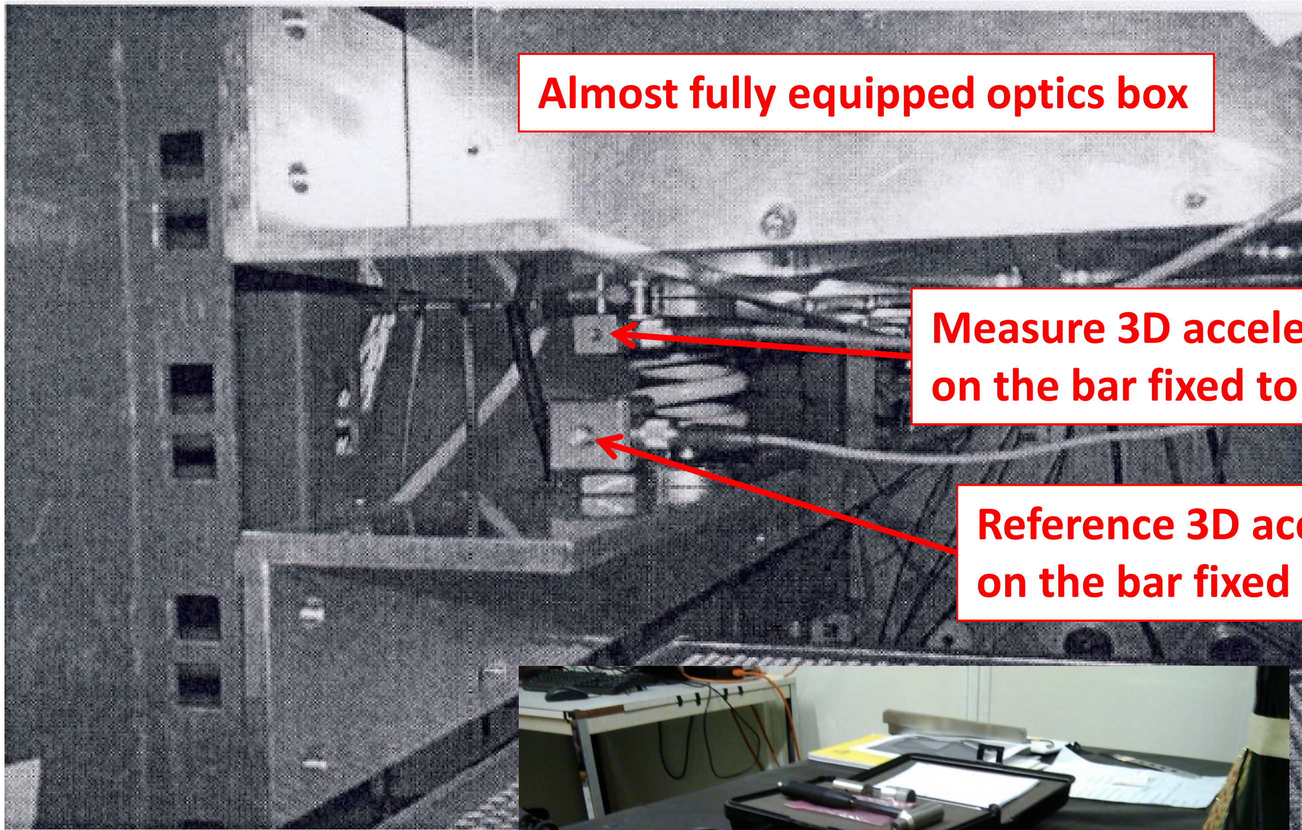
This is the most compact design we considered and it was originally Mounted in hall 175.

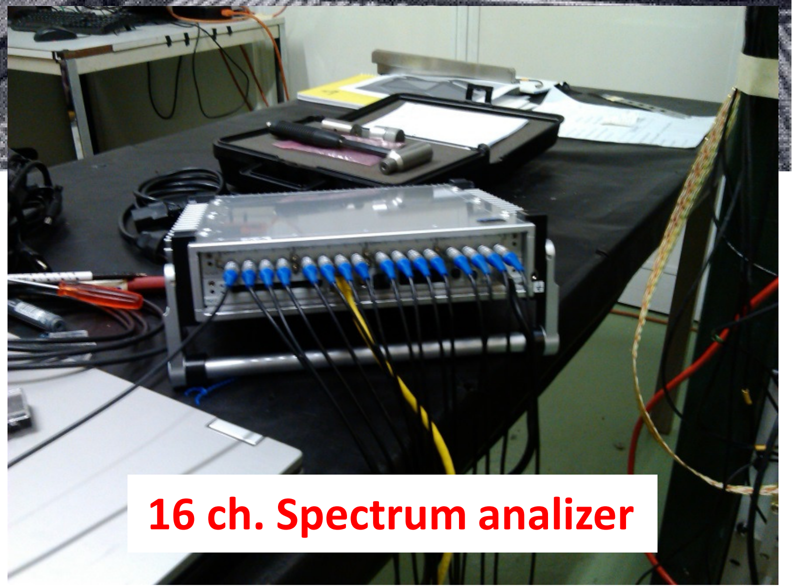
Measurements of the transfer function and of the dumping efficiency were performed by the CERN expert group led by M. Guinchard in January 2014

The two layer configuration is more efficient in dumping vibration, but it is not compatible with the latest C.-F. proposal for the installation in USA-15 (Ph. Gris, Feb. 20, 2014)

*A. Moggi*
*LASERII meeting 11/22/2013*

# Set-up for the measurement of the transfer function




*M. Guinchard, D. Ziemiansky*
*01/23/2014*

# Measurement of the transfer function

*M. Guinchard, D. Ziemiansky*
*CERN EN-MME division*
*02/18/2014*

No description of the theoretical model adopted by the CERN team was given in the released report; we assume they used the following transfer function to fit to the data:

$$|G(f_A)| = \left|\frac{A_{OUT}(f_A)}{A_{IN}(f_A)}\right| = $$

$$= \frac{1}{k} \times \frac{1}{\sqrt{\left(1-\left(\frac{f_A}{f_0}\right)^2\right)^2 + \left(2\varsigma\frac{f_A}{f_0}\right)^2}}$$

$f_o$ = natural frequency
ζ = dumping efficiency
(see below)

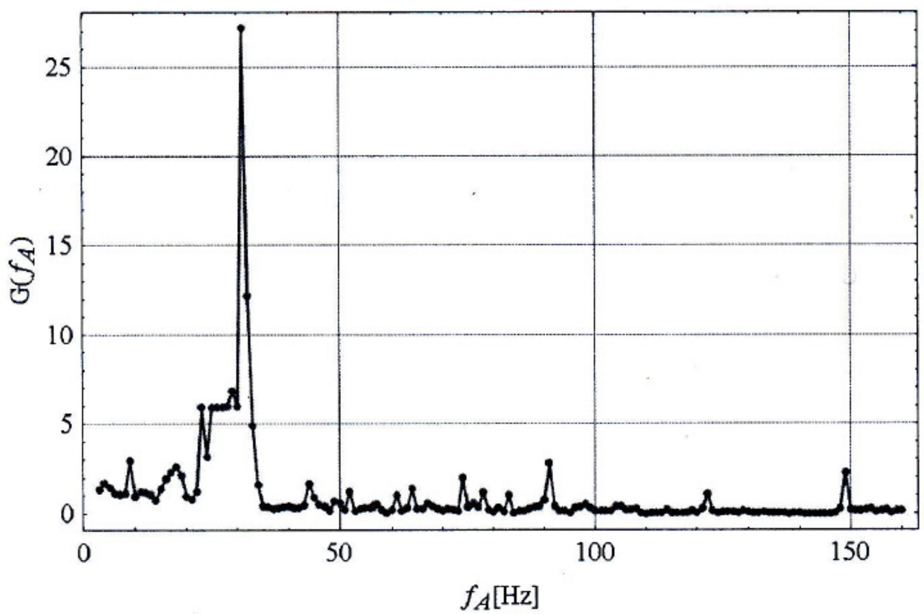


*Fig. 3 Transmissibility characteristics take off from spectrum analyser*

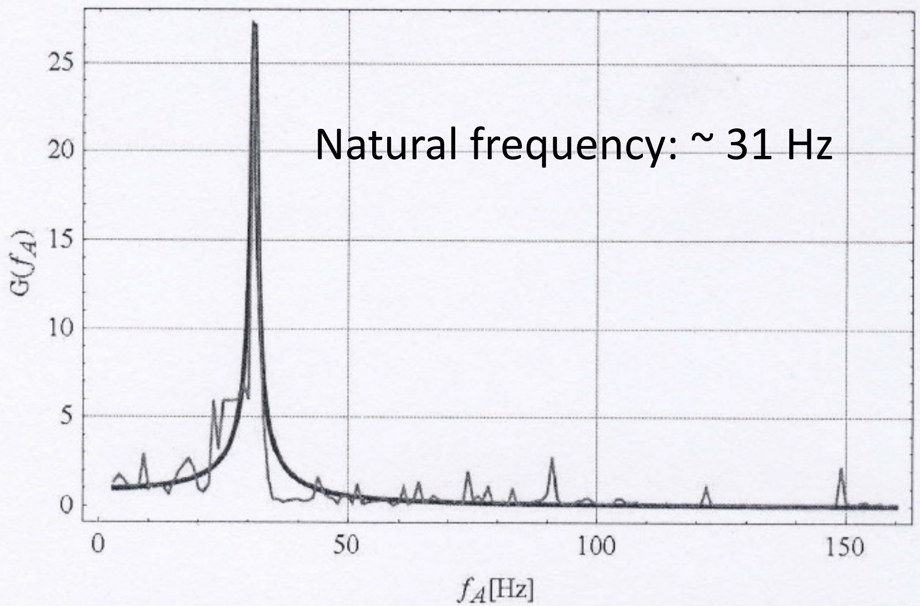


*Fig. 5 Comparison transmissibility characteristics, measurements and theoretical approximati*

# Measured dumping efficiency was poor !

From the fit to the experimental data:

$$f_0 \cong 31[Hz]$$

$$\xi = \frac{c_A}{c_0} = \frac{c_A}{2\sqrt{km}} \cong 0.018$$

We selected the spring model with the lowest natural frequency ($f_n$ = 6 [Hz]) and the largest elastic constant ($k$ = 16,5 [daN/mm]); *a posteriori* we know that we respected the prescription to have $f_n < 3\, f_0$ , but the springs are too ''soft''.
(Producers never quote the dumping coefficient $c_A$ which is a complicated function the material composition and of the stress conditions)

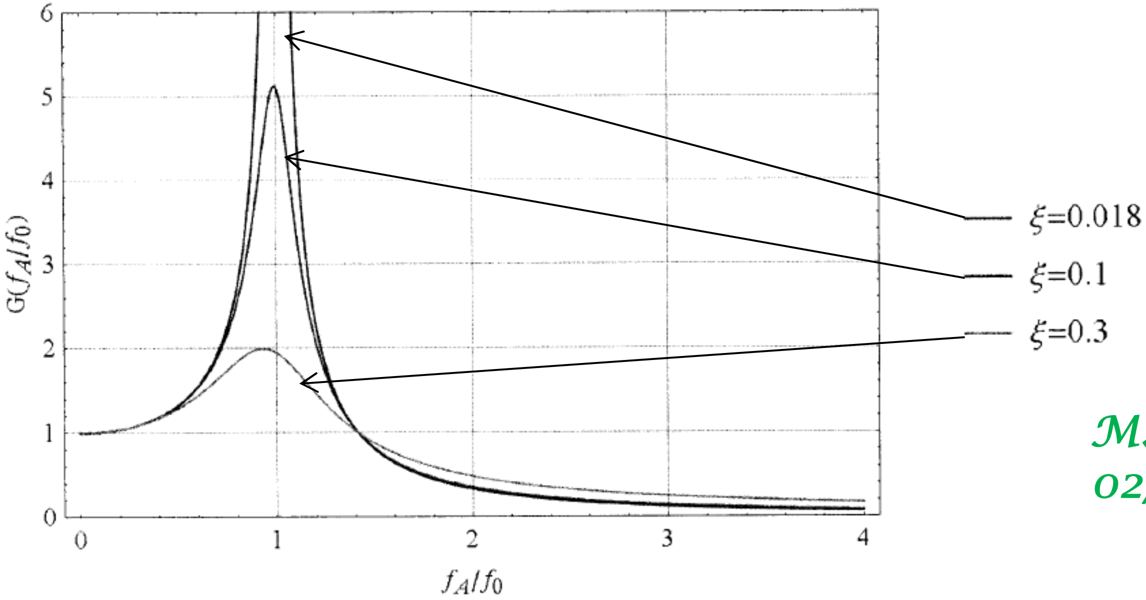



*Fig. 8 The influence of the damping factor to behavior of the system*

*M. Guinchard, D. Ziemiansky*
*02/18/2014*

# Further actions taken …

- The measurement made by the CERN staff turned out to be very expansive ! 2,500 CHF !
- Very poor or null feedback (apart the bill) from the persons having done the measures …
- We decided to find a much less costly way to make trasnfer function measurements and data reduction:
  a) established a collaboration with the Virgo colleagues to use their accelorometers
  b) prepared a simple SW package to analyze data.
- The spectra of the measured transfer functions are stored by the analyser on ascii files.
- We have set-up a Root based package to fit to the data the theoretical distribution of the transfer function of a driven dumped harmonic oscillator; this way, we should extract the correct natural frequency $f_o$ of the system and the dumping factor (efficiency) $\xi$ of the viscous medium (rubber in the Vibrostop Mopla-AA100 model).
- We tested the SW package with the data taken at CERN with the present system (springs w/o rubber/aluminum wafers) and we compared our results with the ones in the EN-MME report.

# SW for data reduction

## 1): storing the data taken in Feb. 2014 in 175

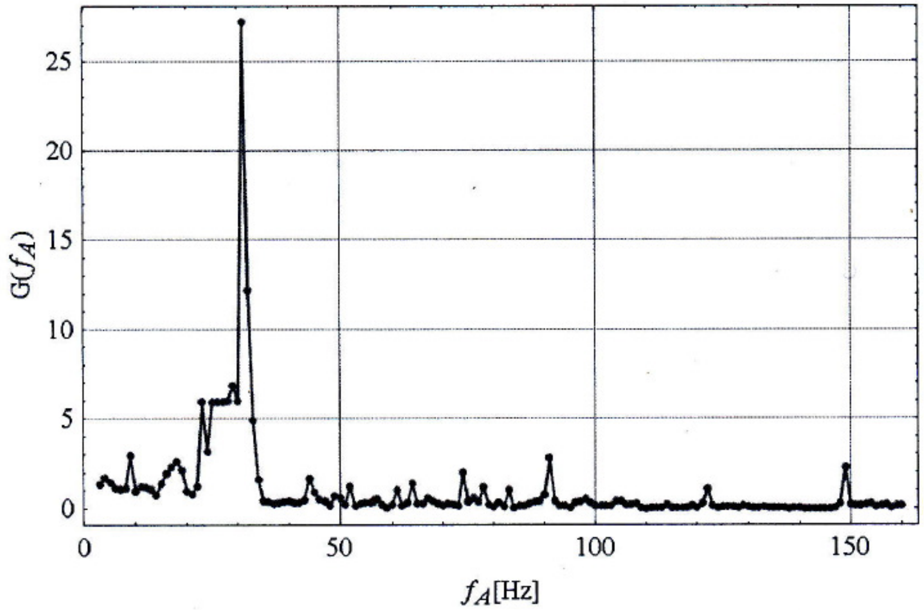
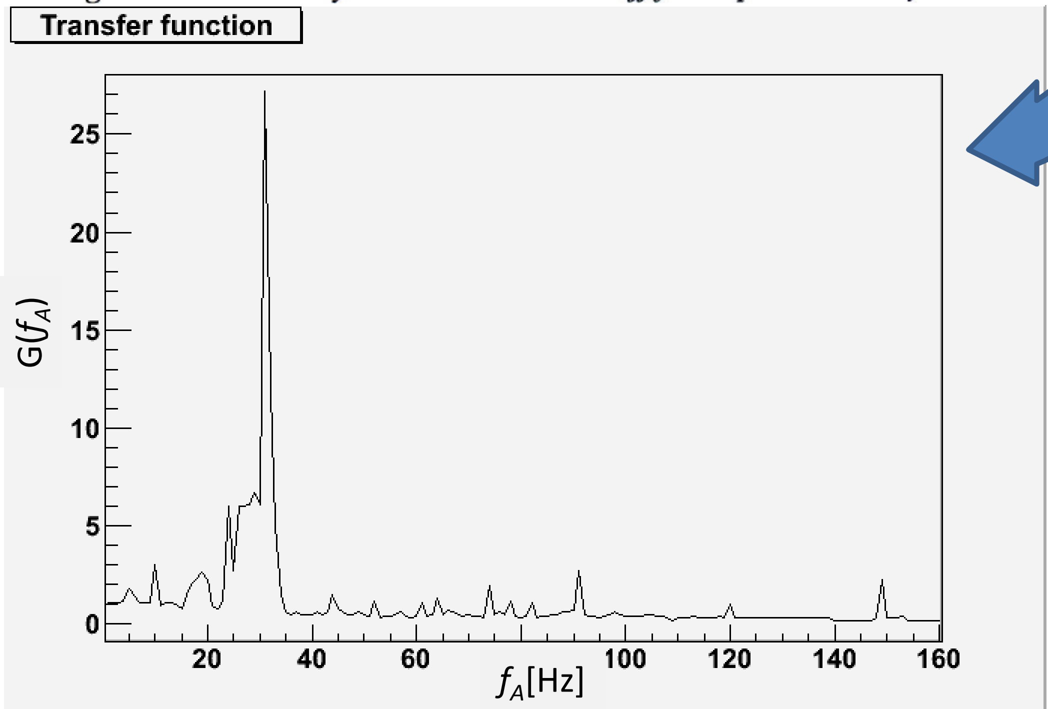



*Fig. 3 Transmissibility characteristics take off from spectrum analyser*




Evaluated *by eyes* the bin content of the plot in the EN-MME report and transferred it into a txt file readout inside a Root macro

# SW for data reduction
# 2): recalling the formalism of the *driven dumped* harmonic oscillator

Equation of the ***dumped*** oscillator: $$m\frac{d^2x}{d^2t}+c_{Dump}\frac{dx}{dt}+k\cdot x=0$$

if $\omega_0^2=\dfrac{k}{m}$ is $2\pi$ times the natural frequency $f_0$

and $\xi=\dfrac{c_{Dump}}{m\cdot\omega_0}$ is the dumping ratio (efficiency)

➡ $$\frac{d^2x}{d^2t}+\xi\cdot\omega_0\frac{dx}{dt}+\omega_0^2\cdot x=0$$

Equation of the ***dumped*** oscillator ***driven*** by a forcing term at frequency $f_A=\omega_A/2\pi$

intensity $\omega_0^2\,\mathrm{X_{IN}}(\omega_A)$

and amplitude $\mathrm{X_{IN}}(\omega_A)$

$$(1)\quad \frac{d^2x}{d^2t}+\xi\cdot\omega_0\frac{dx}{dt}+\omega_0^2\cdot x=\omega_0^2\mathrm{X_{IN}}(\omega_A)\cos(\omega_A\cdot t)$$

Solution of equation (1) is of type : $$x(t,\omega_A)=\mathrm{x_{OUT}}(\omega_A)\cdot\cos(\omega_A\cdot t+\phi_A)$$

with amplitude $$(2)\quad \mathrm{x_{OUT}}(f_A)=\frac{\mathrm{X_{IN}}(\omega_A)}{\sqrt{\left(1-\left(\frac{\omega_A}{\omega_0}\right)^2\right)^2+\left(\xi\frac{\omega_A}{\omega_0}\right)^2}}=\frac{\mathrm{X_{IN}}(f_A)}{\sqrt{\left(1-\left(\frac{f_A}{f_0}\right)^2\right)^2+\left(\xi\frac{f_A}{f_0}\right)^2}}$$

( if you don’t believe it, visit for instance http://farside.ph.utexas.edu/teaching/315/Waves/node12.html )

# SW for data reduction
# 3): fit of the "theoretical" transfer function to the data

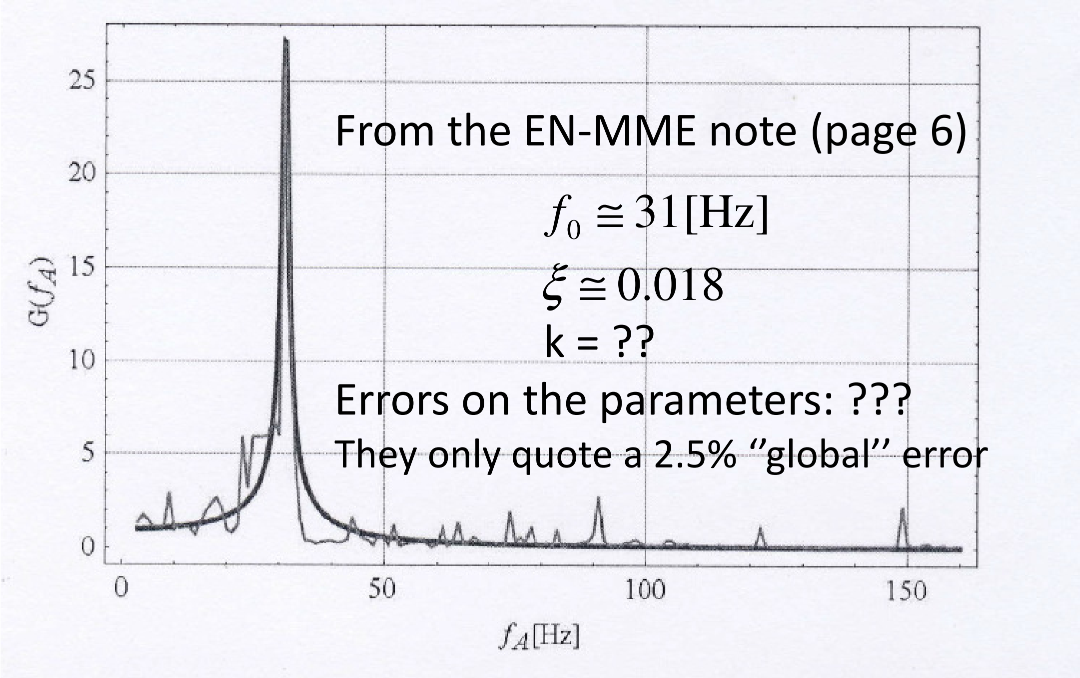
According to equation (2), the " theoretical" transfer function is :

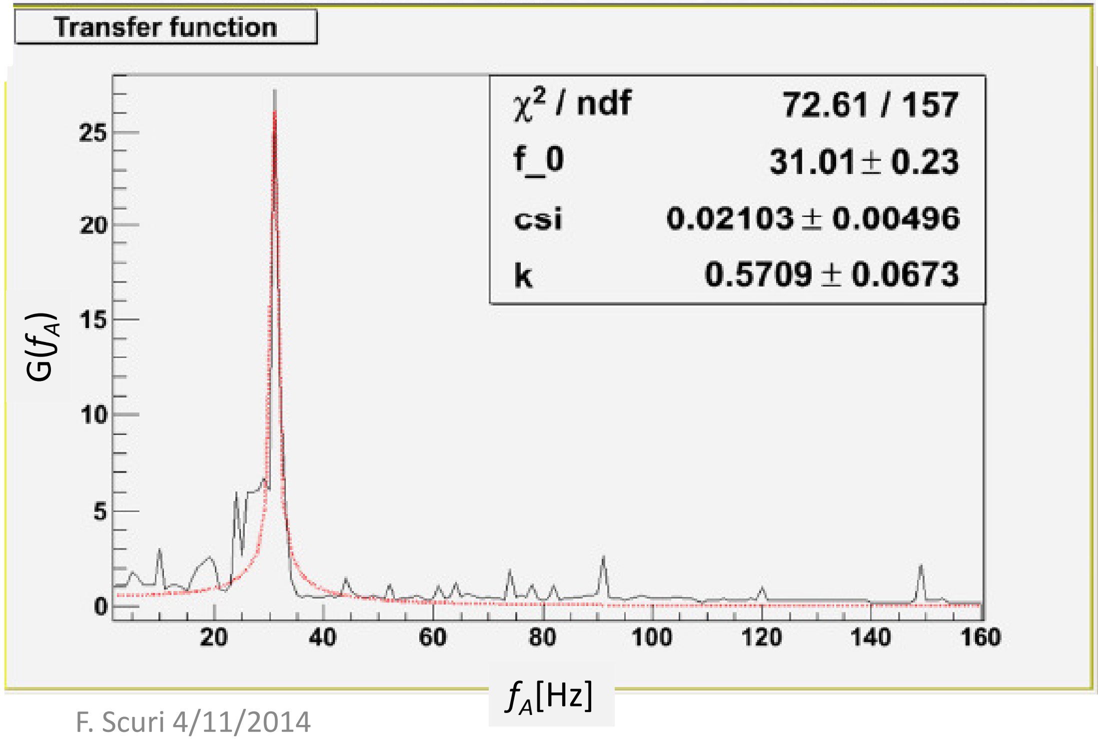
$$\left|G(f_A)\right| = \left|\frac{x_{OUT}(f_A)}{X_{IN}(f_A)}\right| = \frac{1}{\sqrt{\left(1-\left(\frac{f_A}{f_0}\right)^2\right)^2 + \left(\xi\frac{f_A}{f_0}\right)^2}}$$

However, an additional scale parameter k is needed to account for different amplification gains of the measure and reference accelerometers:

$$k = \frac{A_{measure}}{A_{reference}}$$

$$\left|G(f_A)\right| = \left|\frac{x_{OUT}(f_A)}{X_{IN}(f_A)}\right| = \frac{k}{\sqrt{\left(1-\left(\frac{f_A}{f_0}\right)^2\right)^2 + \left(\xi\frac{f_A}{f_0}\right)^2}}$$




# SW for data reduction

## 4): comparison of the data analyses

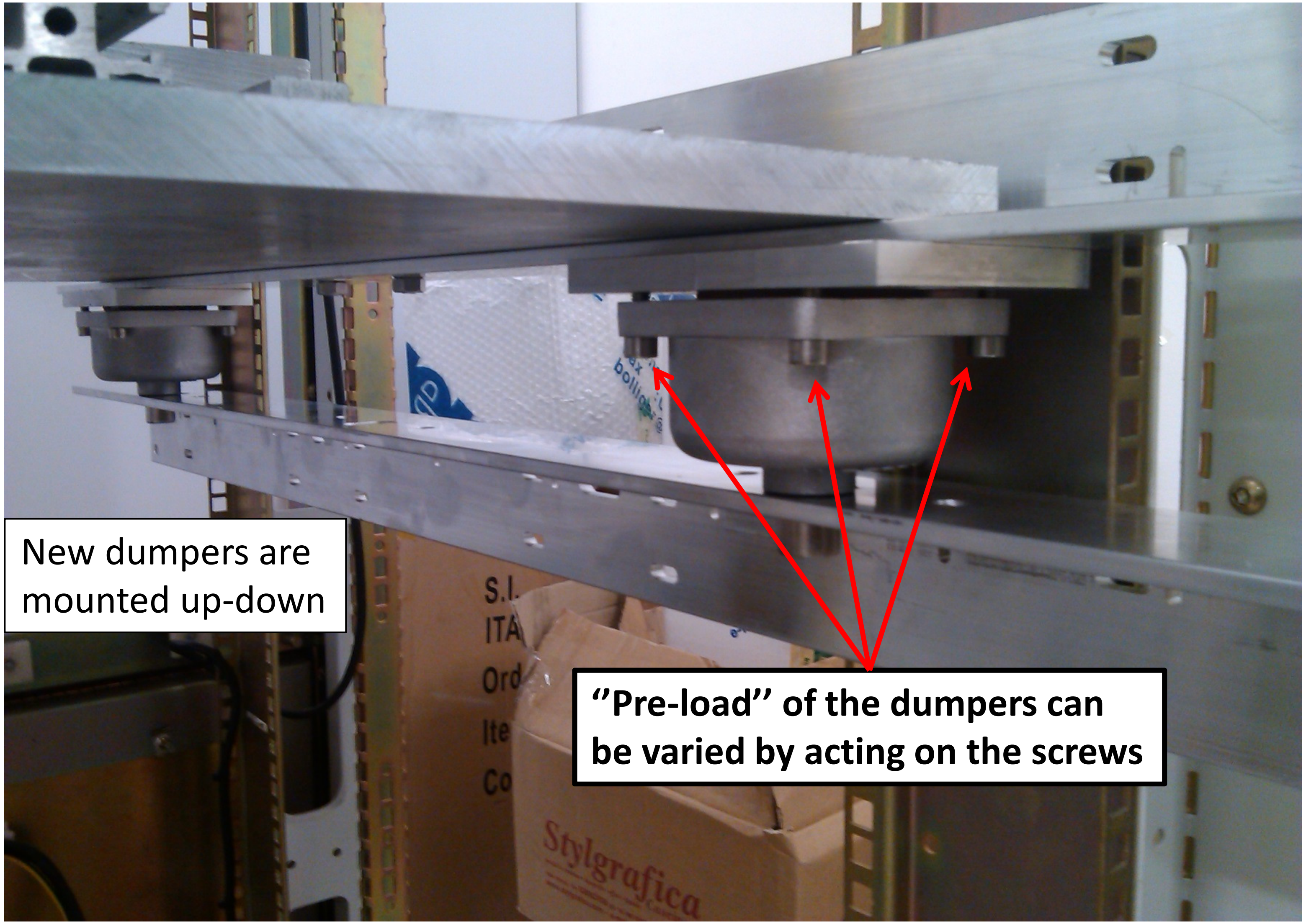
CERN/EN-MME analysis:

- Not described either the adopted theoretical model, and the fit procedure;
- Delivery time of the results : 1 month
- Analysis cost : 120 CHF of total 2,500 CHF

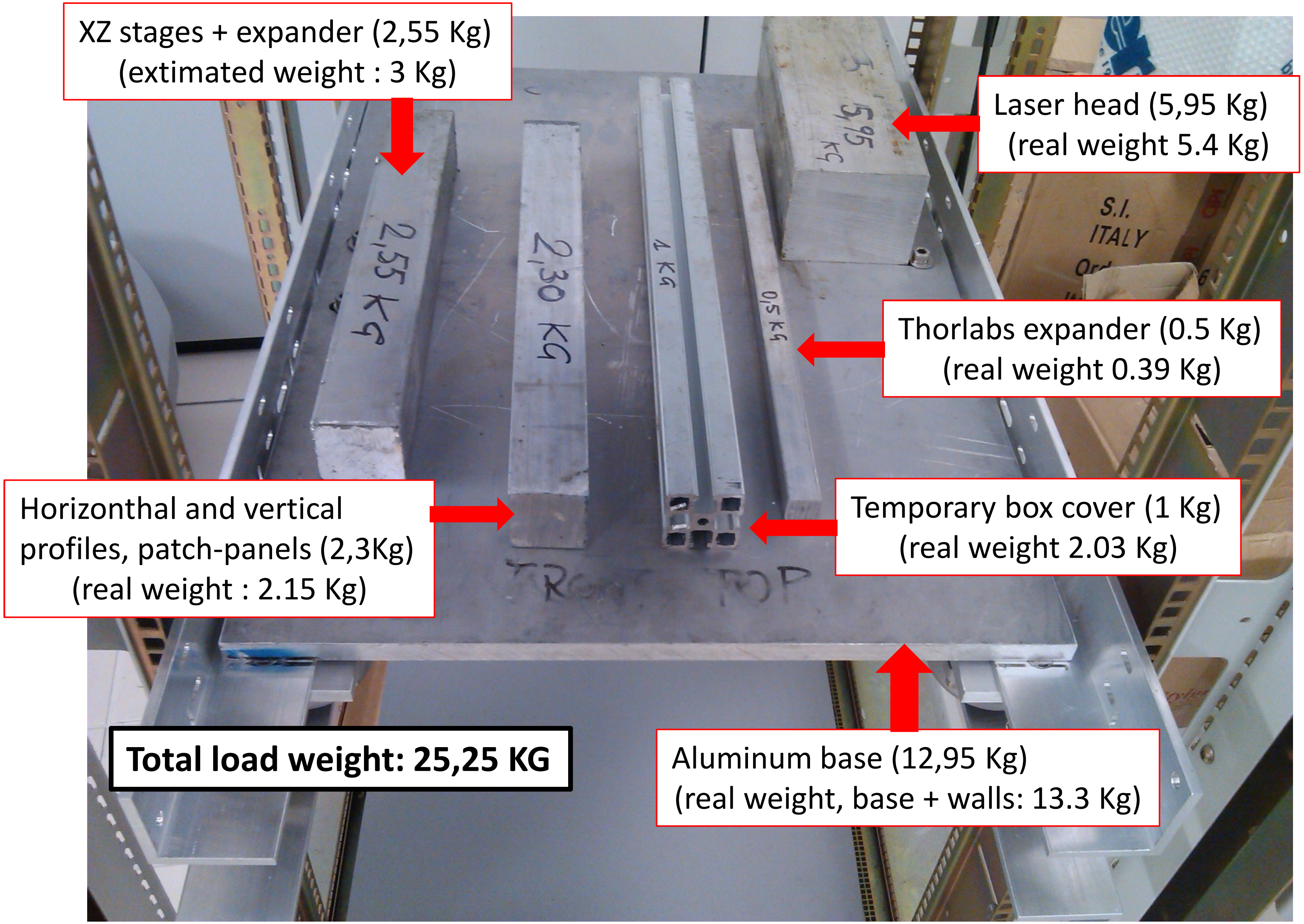
Pisa analysis:

- Model, fit, and SW used available;
- Delivery time of the results : real time;
- Analysis cost : charge free (for the moment)

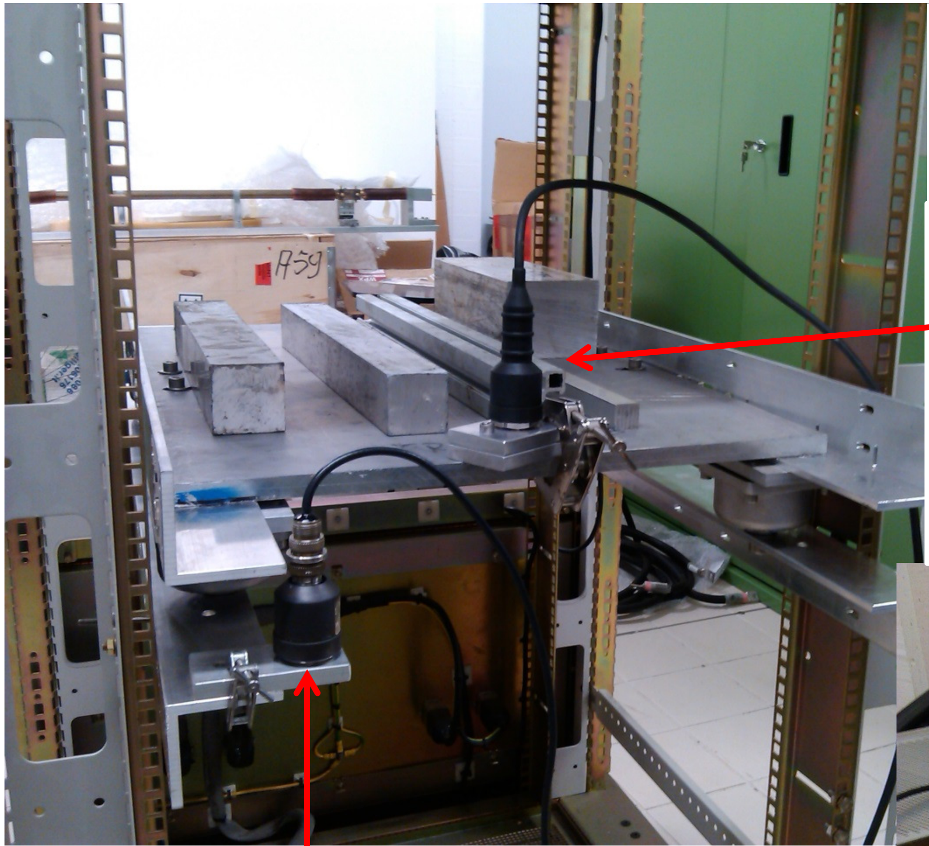
# First measures with a new "flexible" system made in Pisa in April 2014 (V. Boschi, F. Frasconi, A. Gennai, A. Moggi)



# Faking the weight distribution in the optics box ….



# Set-up for the vibration dump measurements in Pisa

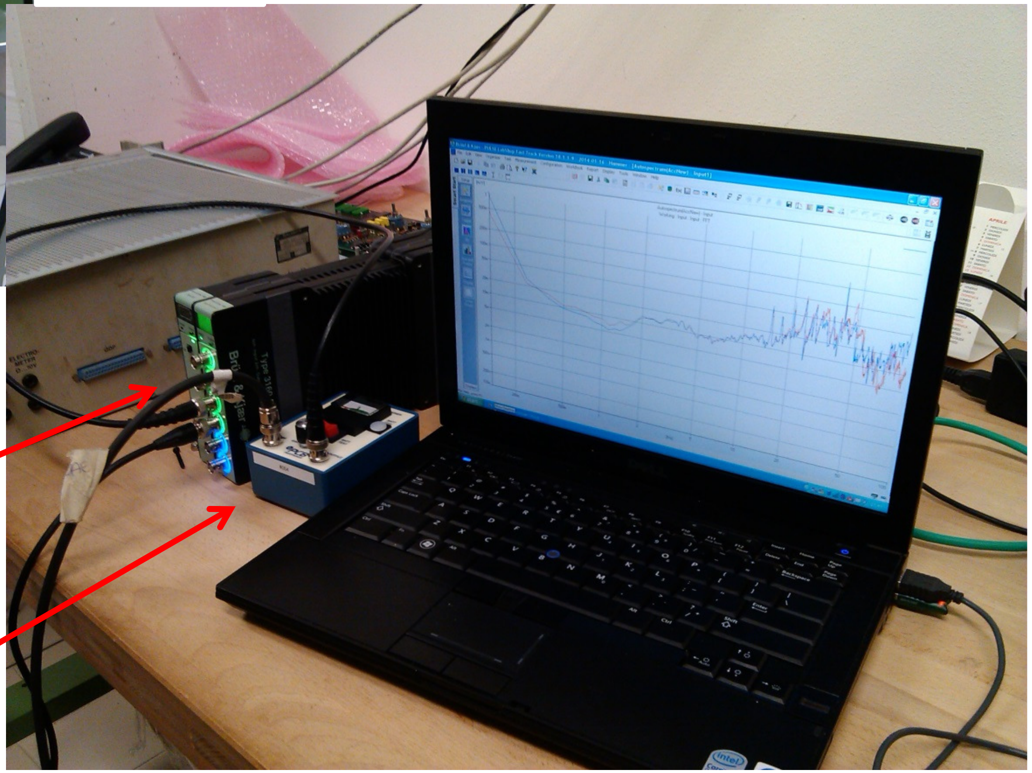


Measure accelerometer

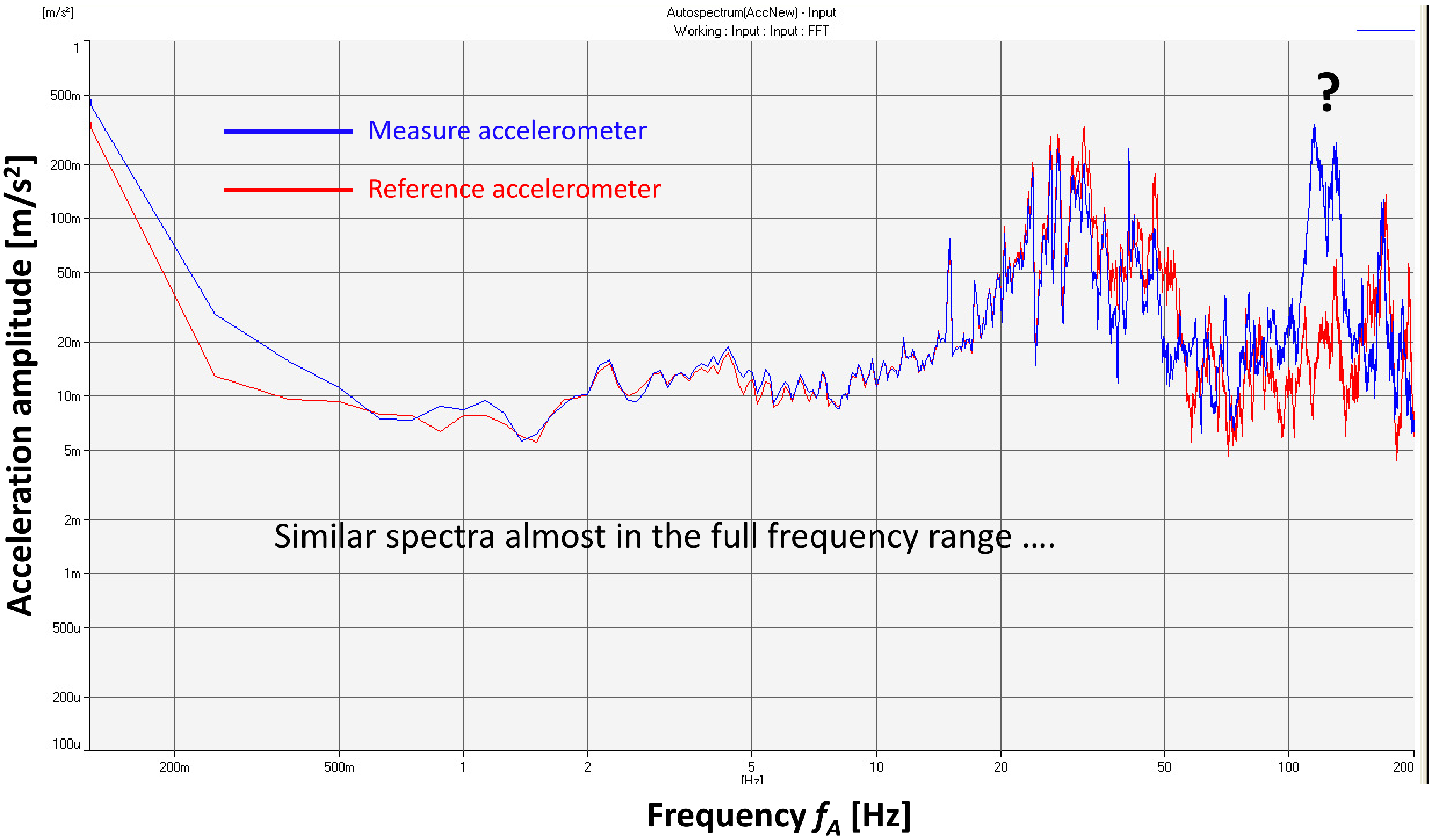
Reference accelerometer
(on the bar fixed to the rack)

6 channel spectrum analyser

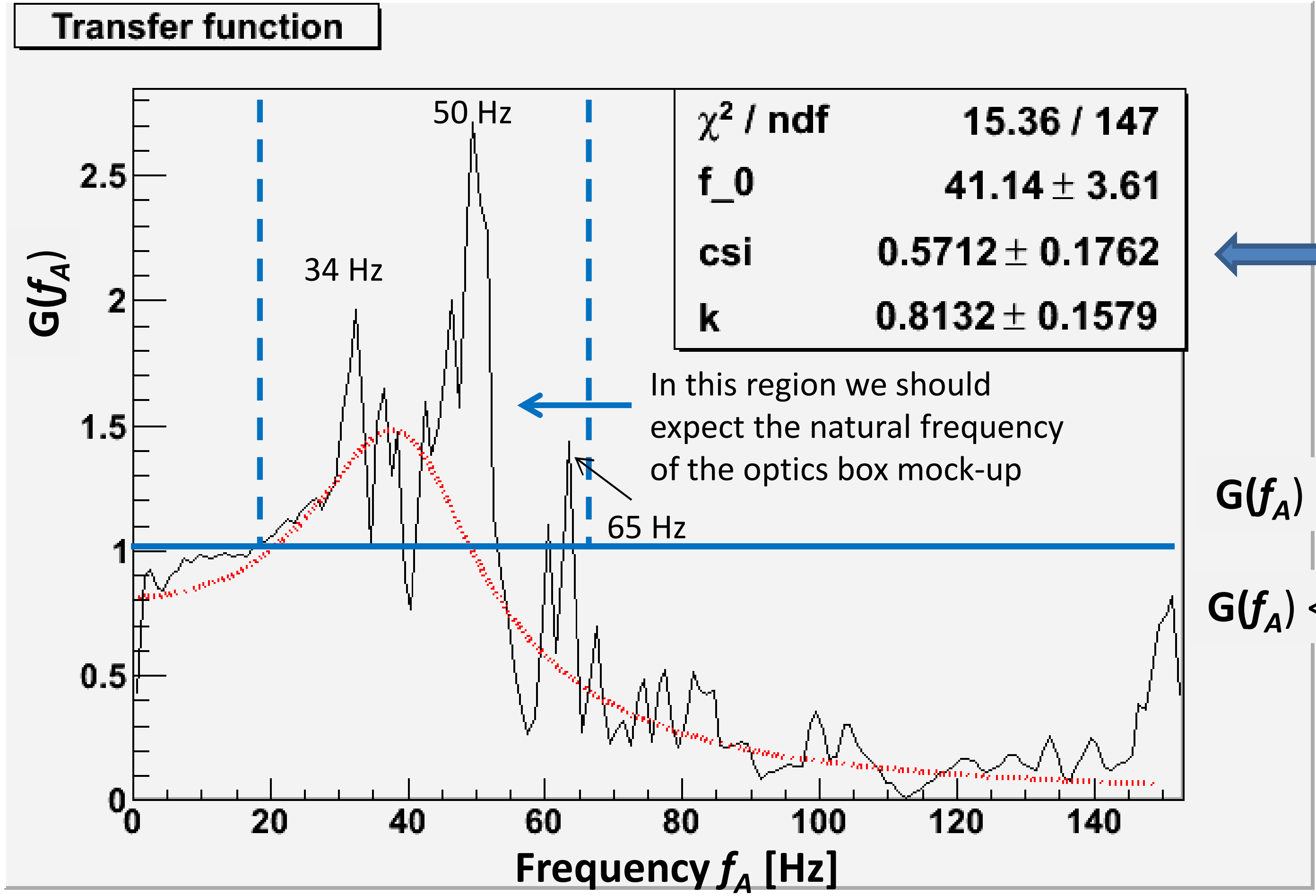
LV power supply for the accelerometers



# Spectral response of the two accelerometers when the system is not excited with the hammer (environmental noise excitation)



# Transfer function of the system not excited with the hammer (environmental noise excitation)

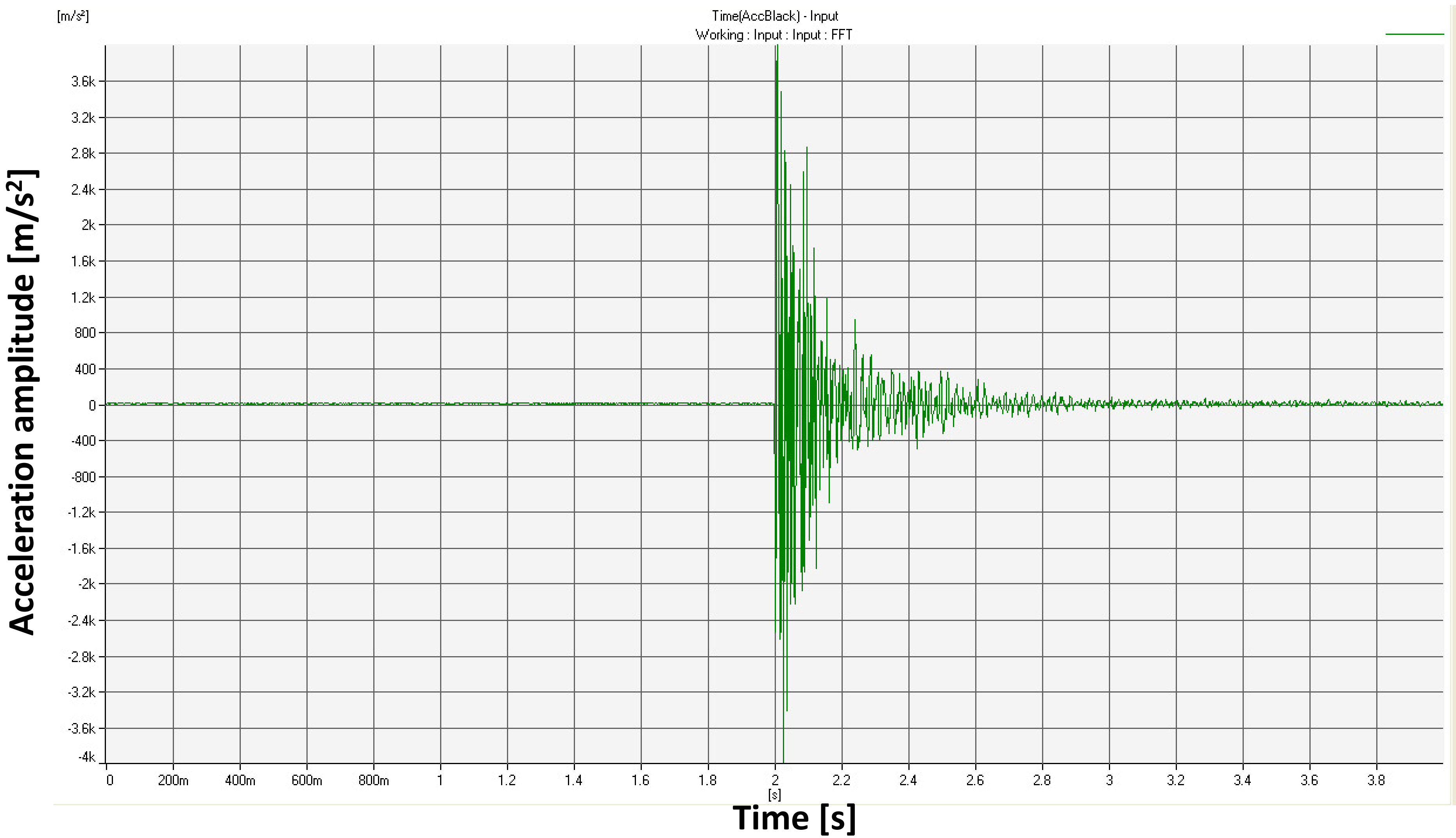



Note the quite good dumping efficiency around 40 Hz

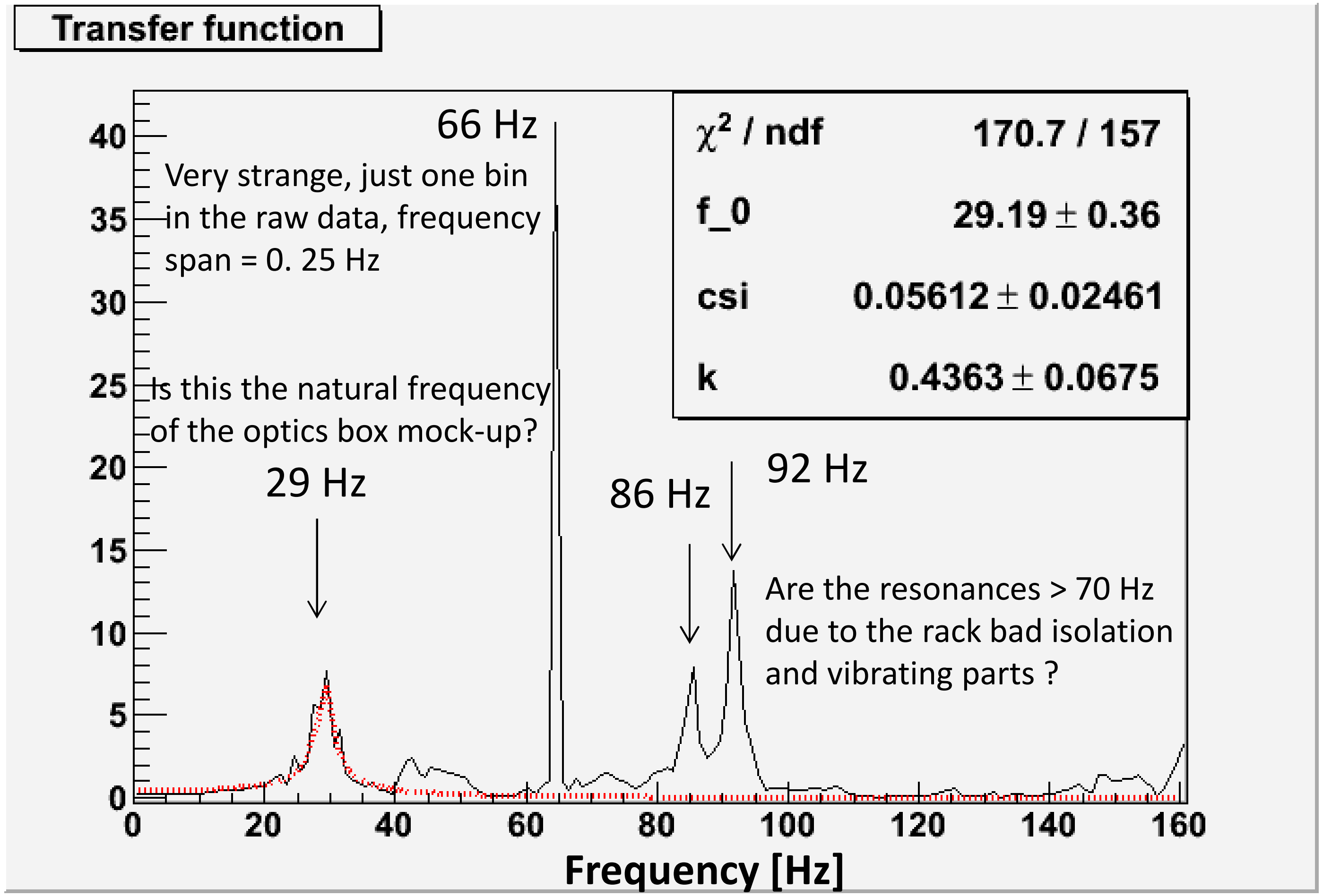
$G(f_A) > 1$ => excited frequency

$G(f_A) < 1$ => dumped frequency

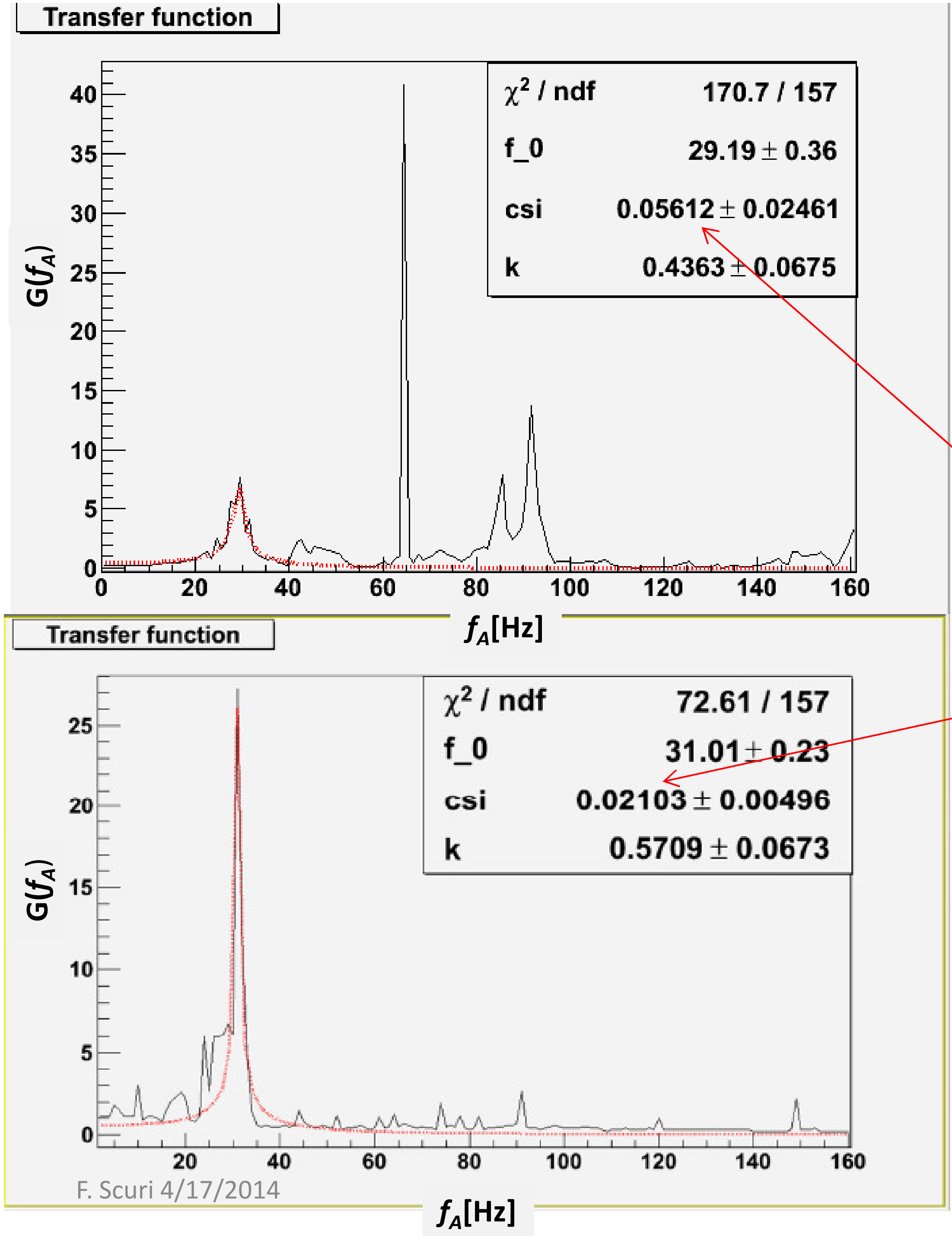
# Typical time response to a hammer shot of the measure accelerometer (placed on the mock-up plate)



# Attenuation of the modes excited with hammer shots




Remark: the relative amplitude of the different resonances strongly depends on the point where the excitation with the hammer is applied on the rack frame.




# Comparison of the transfer function measurments at CERN and in Pisa

Better dumping efficiency at 30 Hz with the rubber bell dumpers

# Summary

1) The transfer function of a vibration dumping system based only on **spring attenuators** with the almost fully equipped optics box was measured at CERN in February 2014:

==> - with a hammer shots only one clear natural frequency **$f_0$ = 31 Hz** was detected with a poor dumping efficiency, $\xi$ **= 2%**
- no environmental noise spectrum (yet) analysed (data without hammer shots should be available ….)

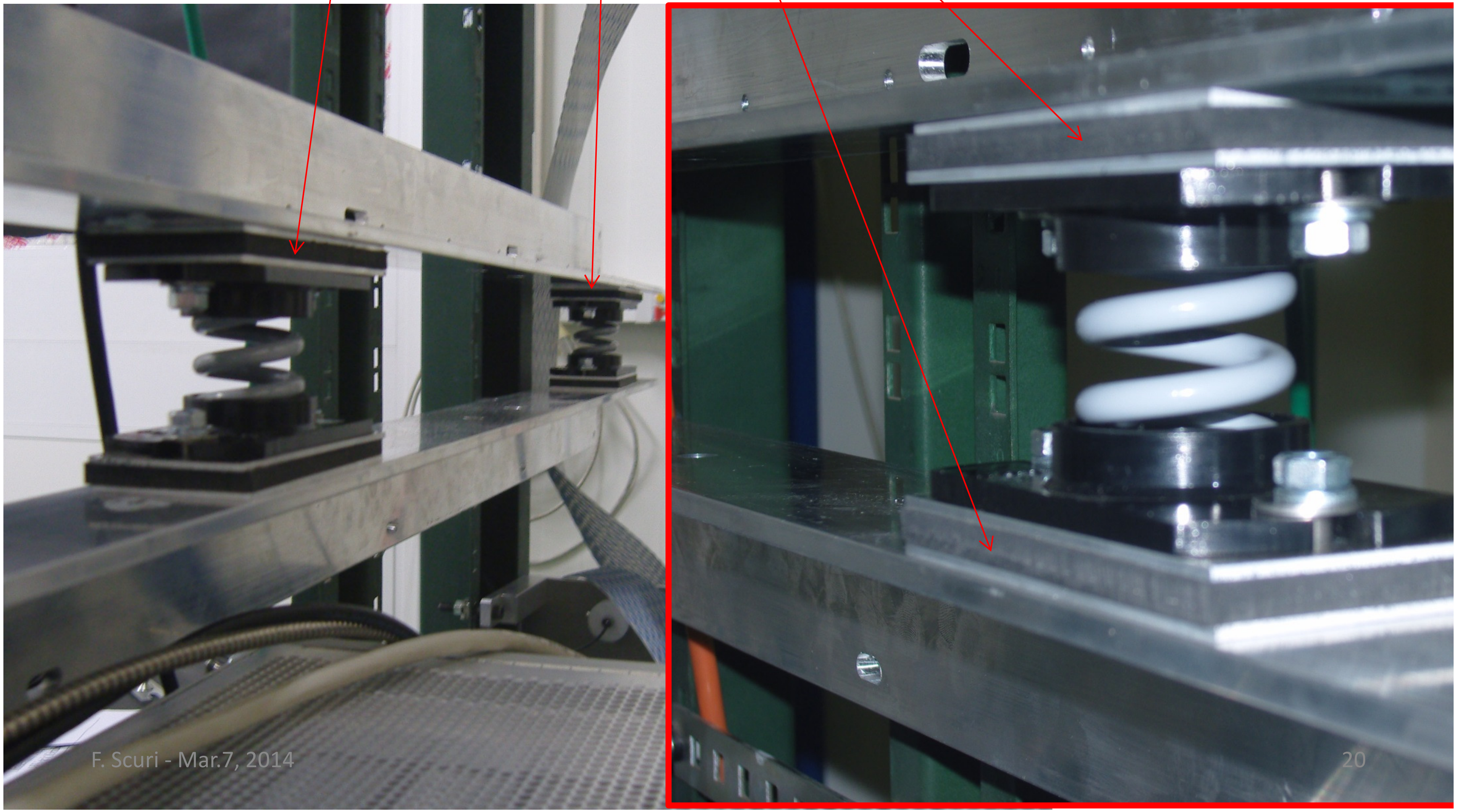
2) The transfer function of a vibration dumping system based on **rubber bell attenuators** with a mock-up of the optics box was measured in Pisa in April 2014:

==> - many resonances were found; we beleive that they mainly come from the bad rack isolation and from internal vibrating machanical parts;
- a natural frequency **$f_0$ = 29.2 Hz** (close to the one of the optics box at CERN) was also detected with a better, but not very high, dumping efficiency, $\xi$ **= 5.5%**

3) We have improved the spring system by adding **rubber layers** which has to be qualified; however, measurements at CERN from the EN-MME group are very expansive, we will first qualify it in Pisa.

# Improved system with springs and rubber layers

Wafers of aluminum plates (needed to uniformely distribute the load) and NPR rubber



# Proposed plan

- Systematic measurements on the two available systems will be performed in June with an improved installation (better isolated rack, no vibrating components, better mock-up of the optics box) in the case of the system exicted with the hammer shot; (we already know that, even in the bad conditions of the last measurement in Pisa, the environmental noise is well dumped by the system for frequencies (>10Hz), just above the typical dumper natural frequency, 6 Hz)

- Once decided whether and which dumping system is suitable, we will organize from July 2014 the installation directly in USA-15 with vibration qualification measures from CERN/EN-MME or Pisa/Virgo.

- This already set a lower limit for the installation time in USA-15 and give us more time to perform long term stability checks in 175.

- Installation of the new optics box on the anti-vibration system is now foreseen for September 2014 ….