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ESRF
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E-beam stabilization experiences at the ESRF

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Outline

- Introduction
- Ground vibration
- Vibration sources identification
- Mechanical design optimization
- Damping device for machine girders
- e-beam feedback

Introduction – *e-beam stability*

- **e-beam size at source points**
  - $RMS_{vertical}$ = 8 µm
  - $RMS_{horizontal}$ = 59 µm for low-β section, 402 µm for high-β section
- **e-beam stability requirement**
  - 20% emittance growth Δε/ε, ~ 10% e-beam size & 10% divergence
  - $\Delta RMS_{vertical}$< 0.8 µm, $\Delta RMS_{horizontal}$ < 6 µm (low-β), 40 µm (high-β)
- **Quadrupole stability requirements**
  - e-beam vibration amplification by optics ~ 20 (V), 30 (H)
  - → quadurpole vibration $RMS_{Q\text{-}vertical}$< 0.04 µm, $\Delta RMS_{Q\text{-}horizontal}$ < 0.2 µm (low-β)
- **Ground stability requirements**
  - quadrupoles vibration amplification : 2 (compared to ground)
  - → ground vibration $RMS_{G\text{-}vertical}$< 0.02 µm, $\Delta RMS_{G\text{-}horizontal}$ < 0.1 µm (low-β)

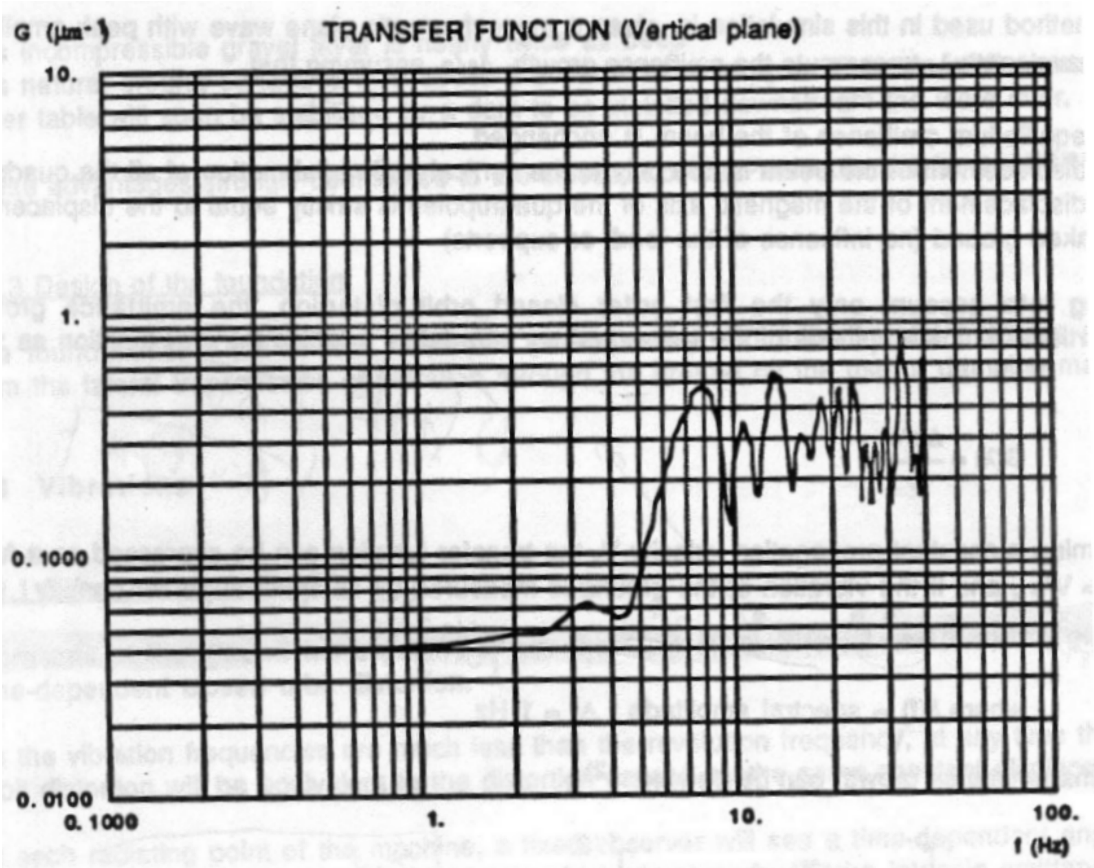
Introduction – *X-ray beam stability*

- **ESRF : synchrotron light source**
- **E-beam stability : quadrupoles, girders, ground**
- **X-ray beam stability**
  - Sample holder
  - X-ray optics (mirror, monochromator)
  - e-beam source
  - Ground
- **X-ray beam stability requirement**
  - X-ray beam size : 0.1 µm ~ a few cm, 10% of size → 0.01 µm
  - Angular stability : better than 0.1 µrad

Introduction

- **Transfer function**
  (ground vibration ***d(f)*** →e-beam emittance growth $\Delta\varepsilon/\varepsilon$)

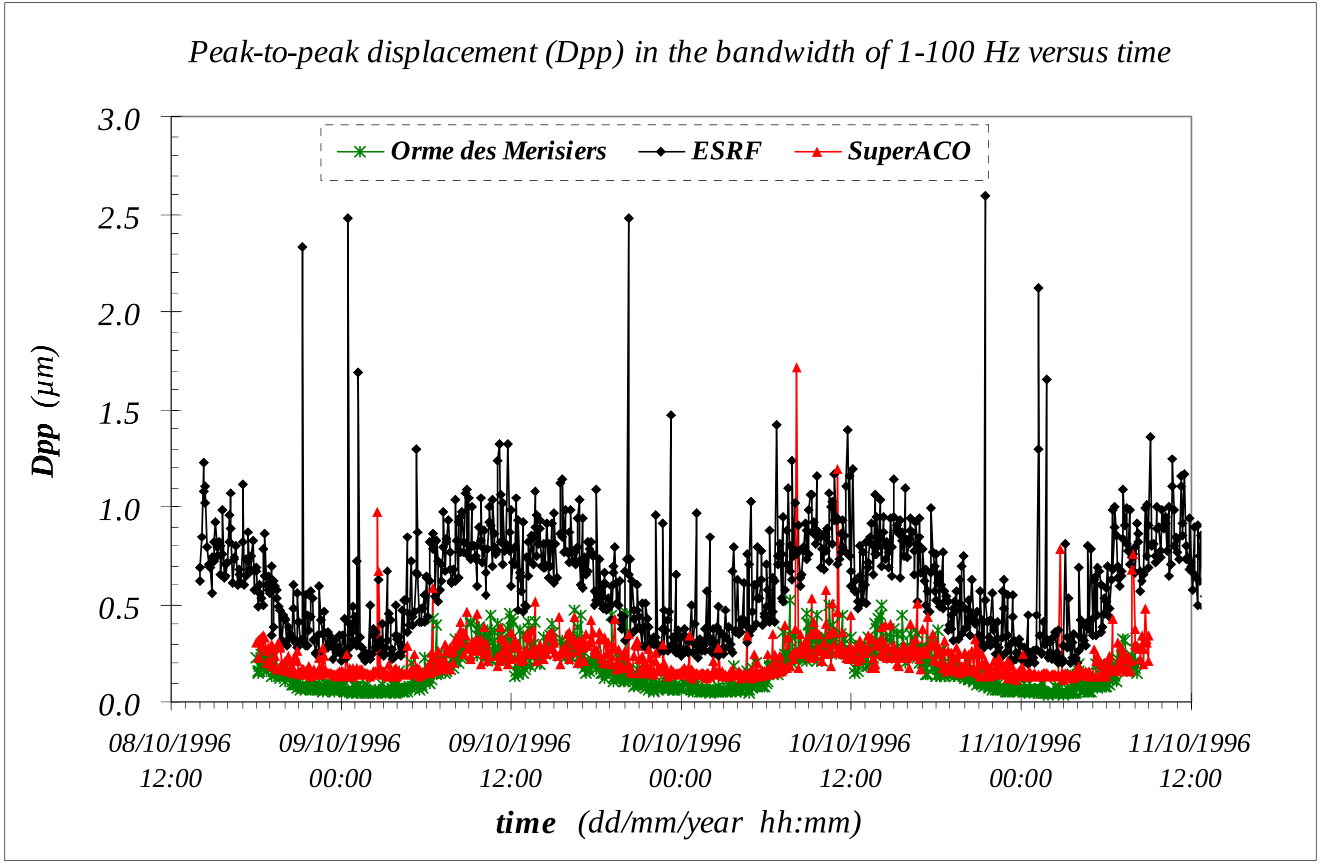
$$G(f) = \frac{\Delta\varepsilon / \varepsilon}{d(f)}$$



→ **e-beam sensitive to vibrations f > 4Hz**

"ESRF foundation phase report", 1987

Ground vibration – *versus time*



Typical values (µ**m**)

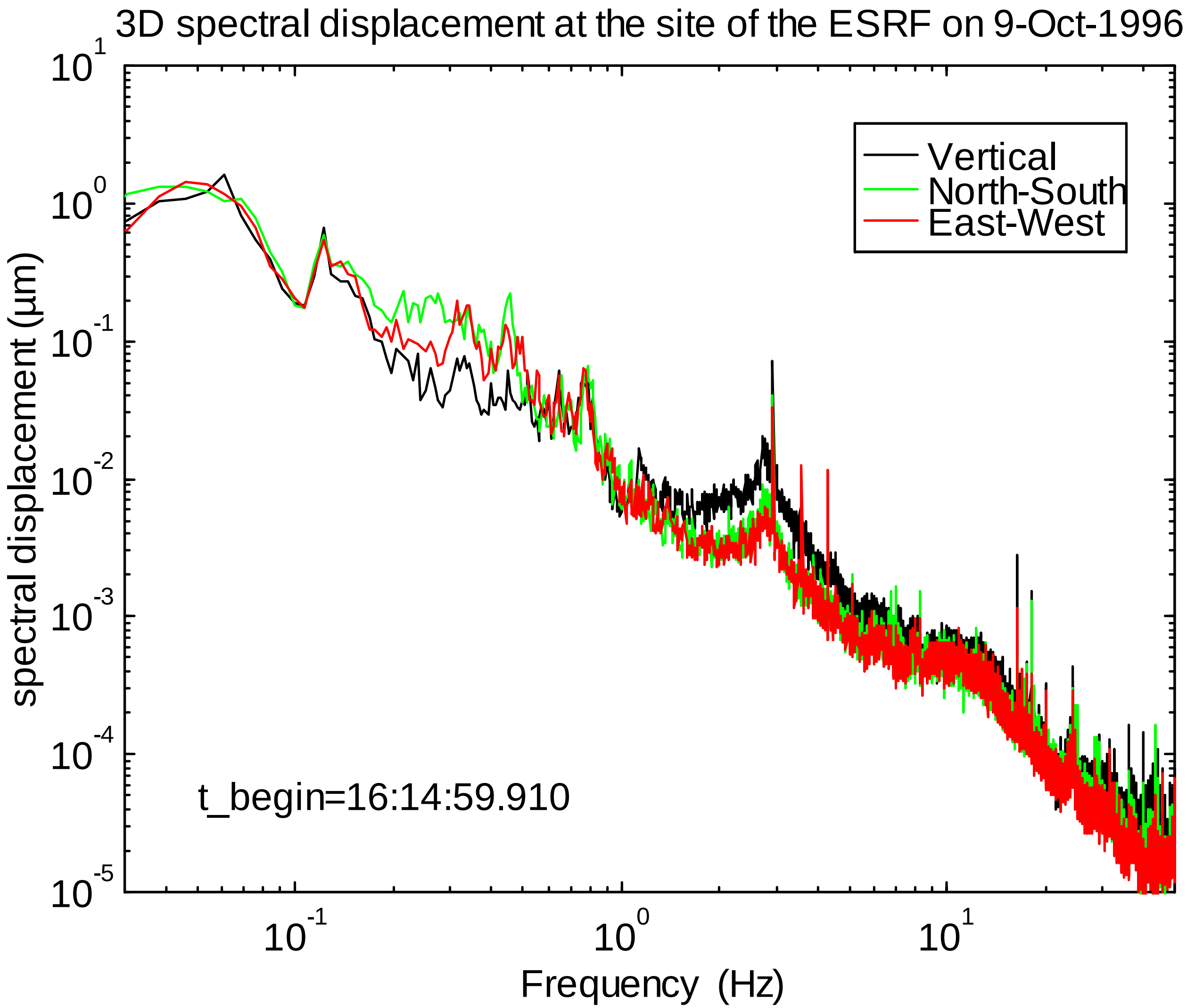
	day	night
P2P	0.80	0.36
RMS	0.12	0.05
$RMS_{4\text{-}100Hz}$	0.04	0.018

Requirements :

$\Delta RMS_{G\text{-vertical}} < 0.02\ \mu m$

$\Delta RMS_{G\text{-horizontal}} < 0.1\ \mu m$

Ground vibration – *3D spectral displacement*



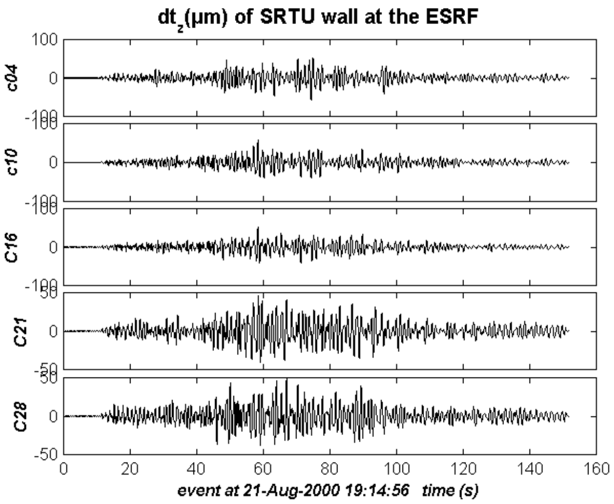
Vibration source identification

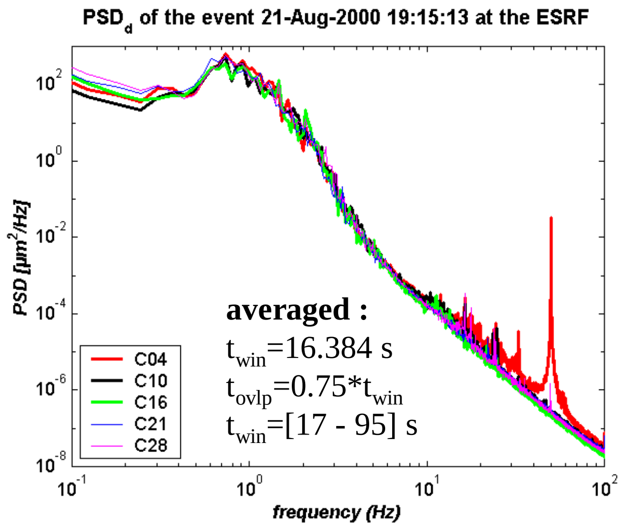
- **Internal sources**
  - Water flow : rubber connection, flexible versus rigid pipes, …
  - Power supply : vibration isolation
  - Ventilations : in SR tunnel, experiment hall, optic table,…

- **External sources**
  - Earthquake
  - Speed bump at the exit of the motorway
  - Road surface near the site (sewer covers, irregularities,…)
  - Speed bump in the site
  - Big machines near the site : compressor, electric-heat co-generator,water pumps,…
  - Traffic : trains, trolley-bus, trucks, buses,…
  - Bridges near the site
  - Grenoble site (3 Hz)

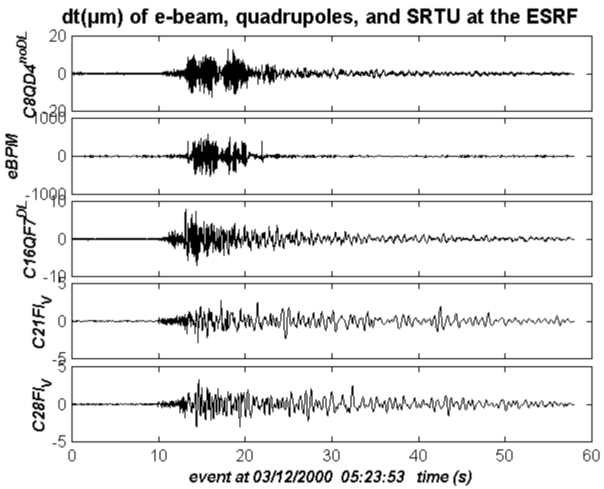
Vibration source identification - *earthquakes*

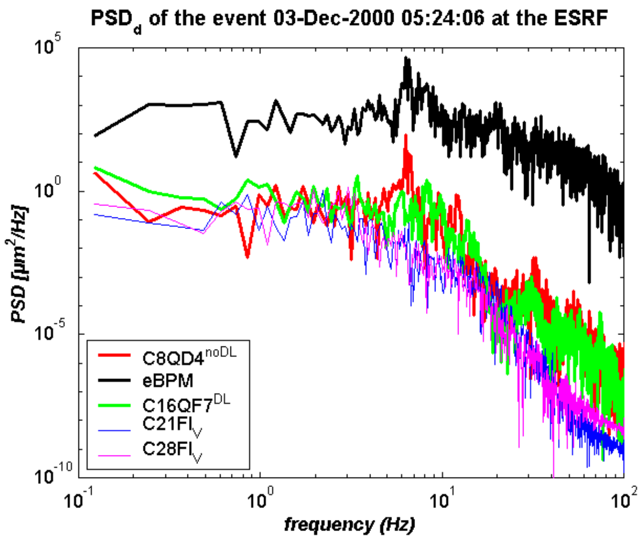
Date : 21/08/2000, 19:14:56 (local time)
Magnitude : 5.0
Epicentre : north of Genes Italy
distance : 200 ~ 250 km





Date : 03/12/2000, 05:24:00 (local time)
Magnitude : 2.3
Epicentre : near Domène France
distance : 15 ~ 20 km



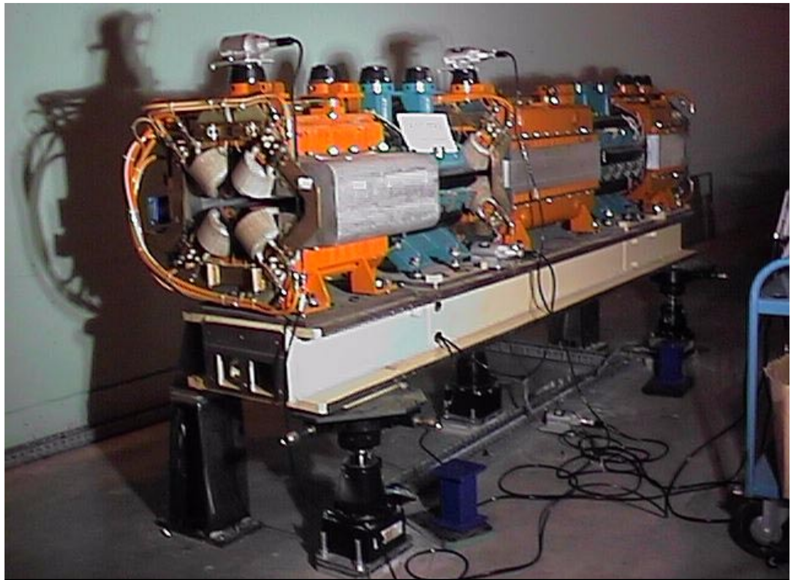


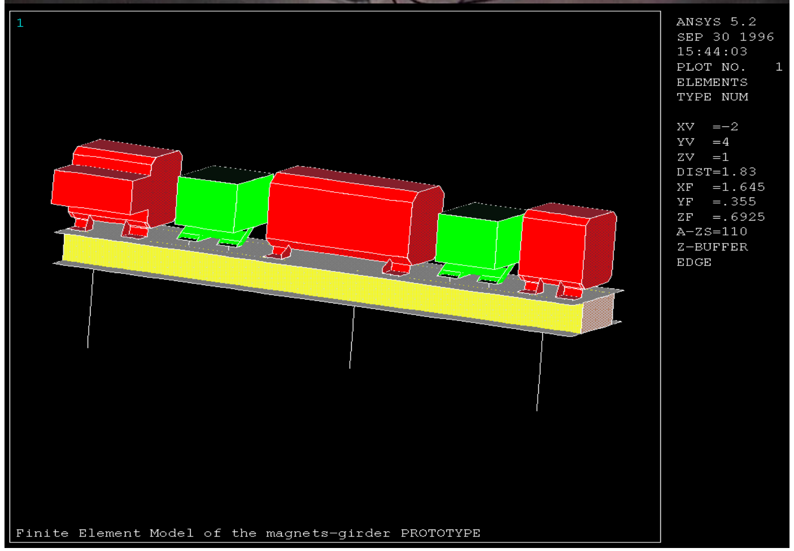
Mechanical design optimization

- **Design guide line :**
  - Natural frequencies : as high as possible
  - → low mass, high stiffness
  - Avoid non necessary adjustments : jacks, translation, rotation stages,…
  - Individual versus grouped supports or tables
  - fixations

  - Finite element simulation

machine girder – *modes identification*



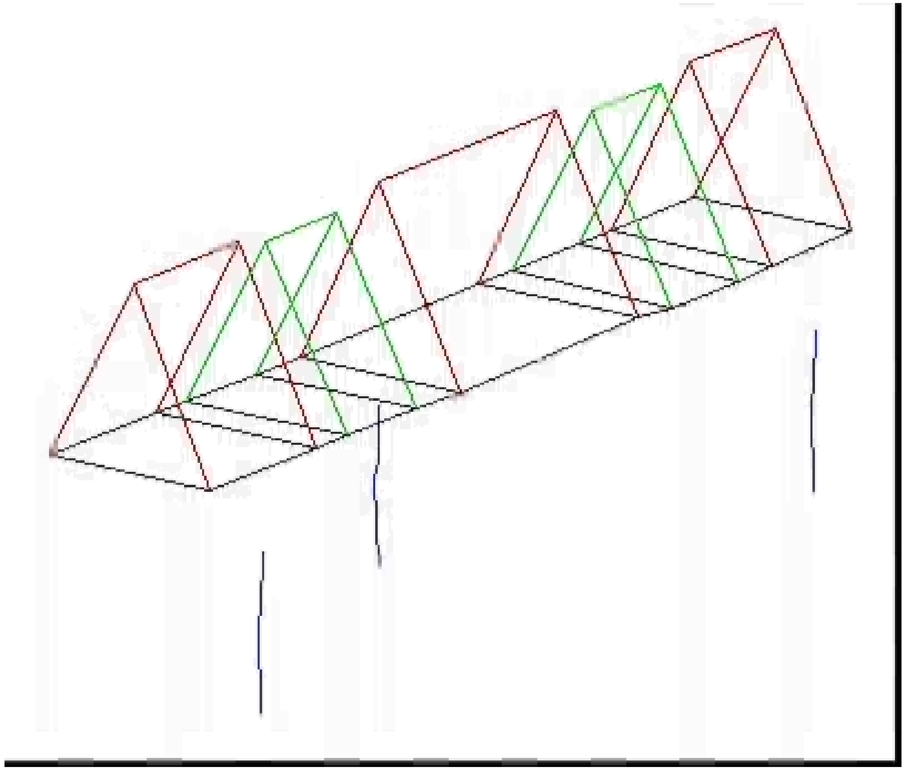


natural frequencies comparison

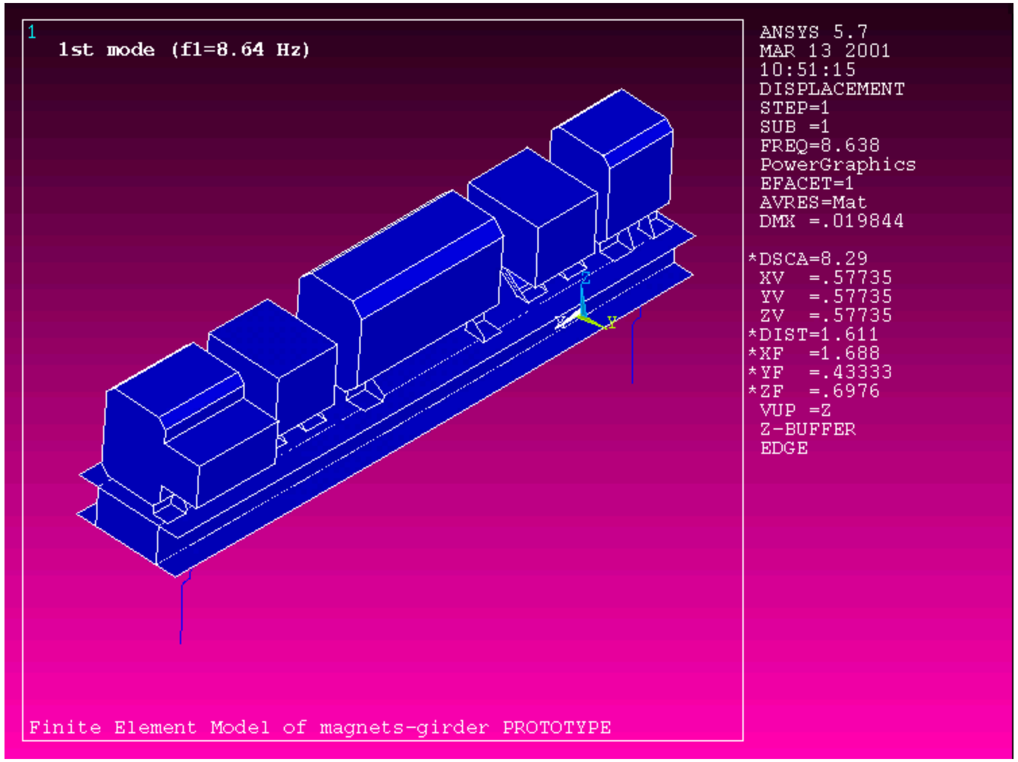
		before tuning		after tuning	
No	f_{TEST}	f_{FEM}	Δ	f_{FEM}	Δ
1	**8.68**	**8.89**	**2.4%**	**8.64**	**-0.5%**
2	**11.74**	**11.64**	**-0.8%**	**11.75**	**0.1%**
3	**13.63**	**12.86**	**-5.6%**	**13.70**	**0.5%**
4	22.33	22.47	0.6%	22.47	0.6%
5	26.29	26.45	0.6%	26.35	0.2%
6	27.82	27.17	-2.3%	27.14	-2.5%
7	32.18	31.58	-1.9%	31.48	-2.2%
8	32.30	33.12	2.5%	33.13	2.6%
9	34.85	36.39	4.4%	36.38	4.4%
10	39.49	38.29	-3.0%	38.28	-3.1%

machine girder – *modes identification*

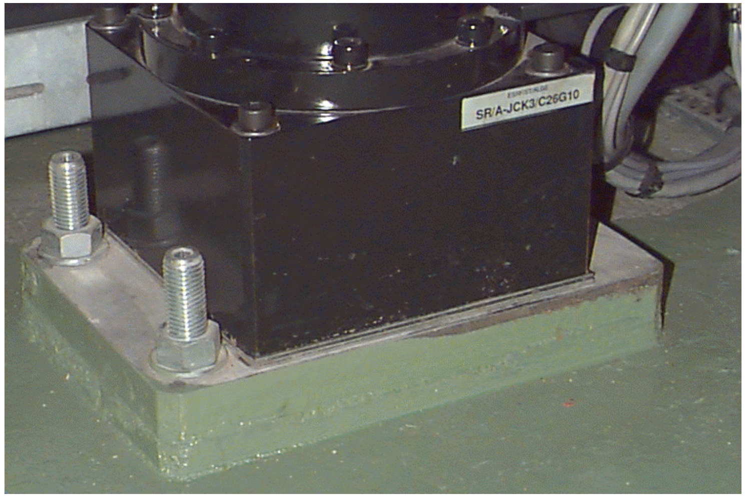
from modal testing

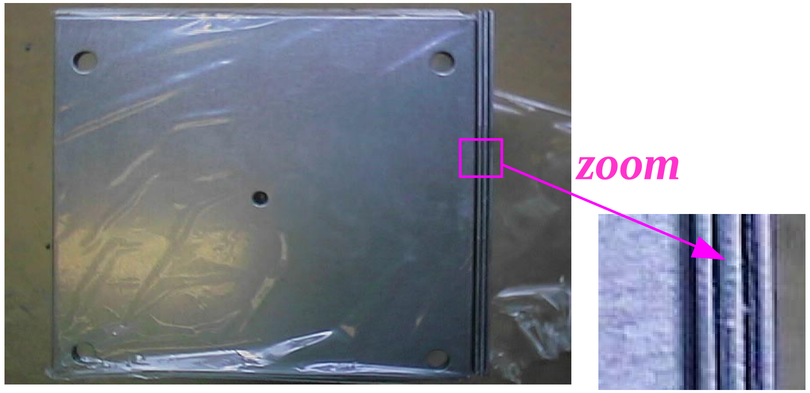


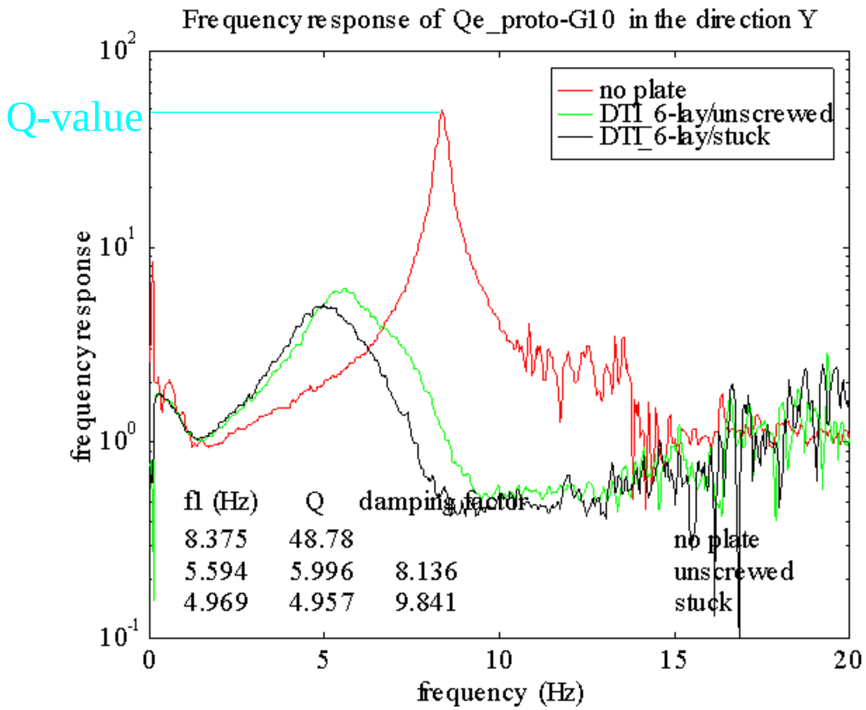
from FEA



Damping device – *damping plates*

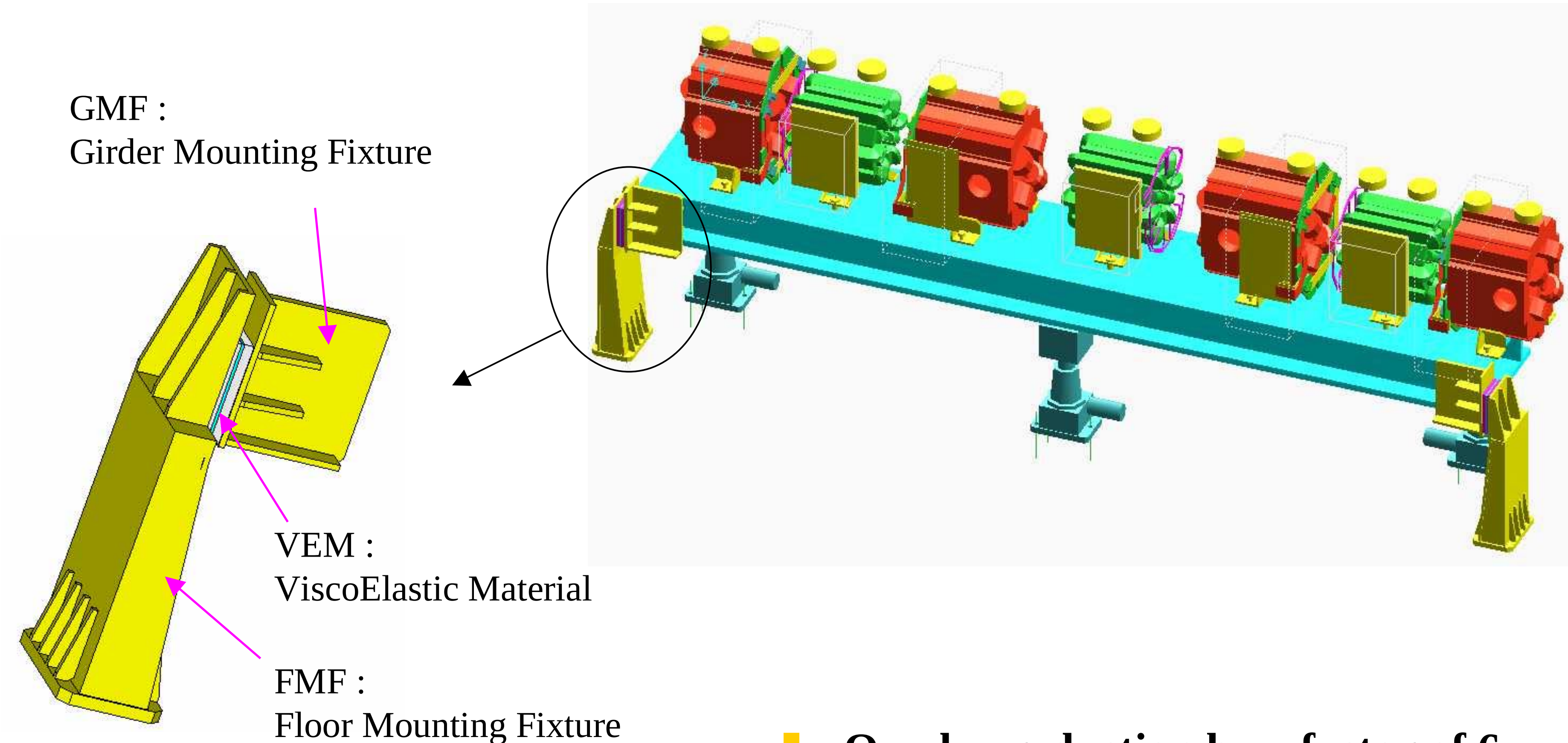






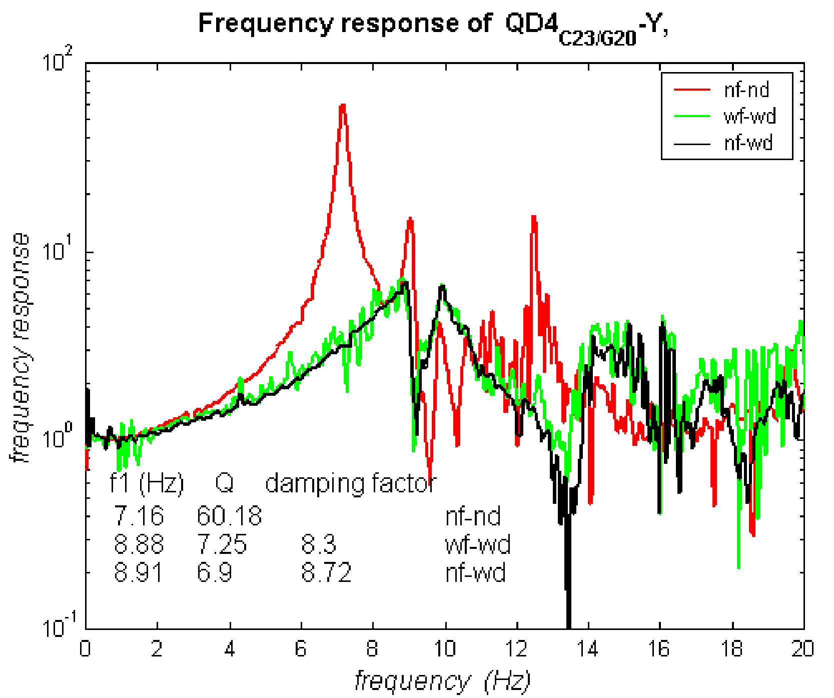
- **Q-value reduction by a factor of 10**
- **Stiffness reduction : position drift**

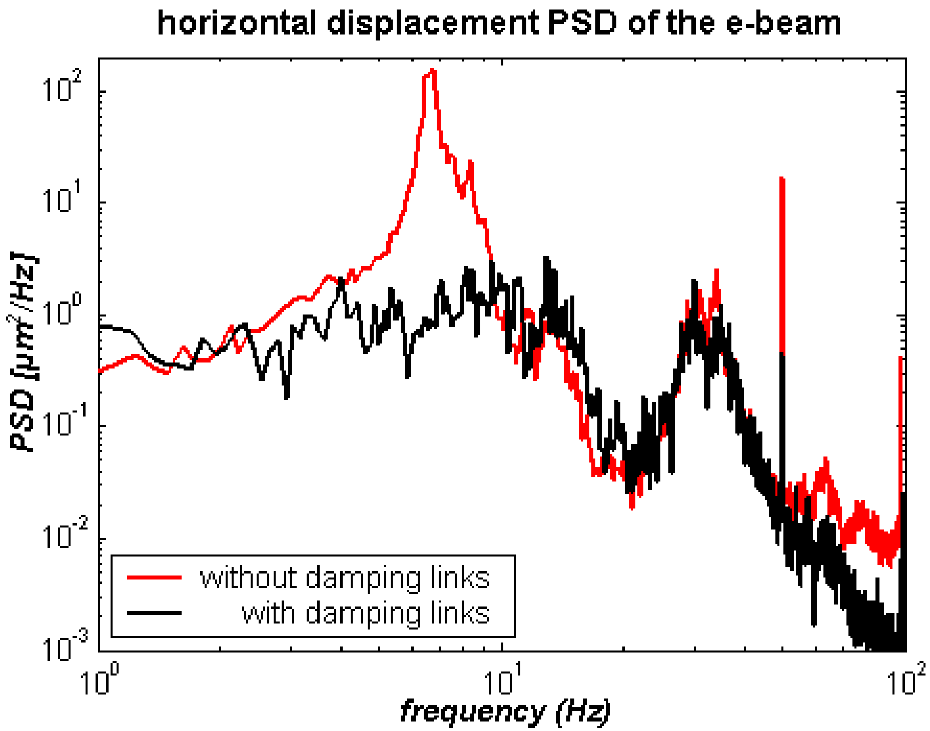
Damping device – *damping link*



- **Q-value reduction by a factor of 6**
- **Stiffness increase : 1st natural frequency shifted to higher frequency**

Damping link for machine girder – *performance*

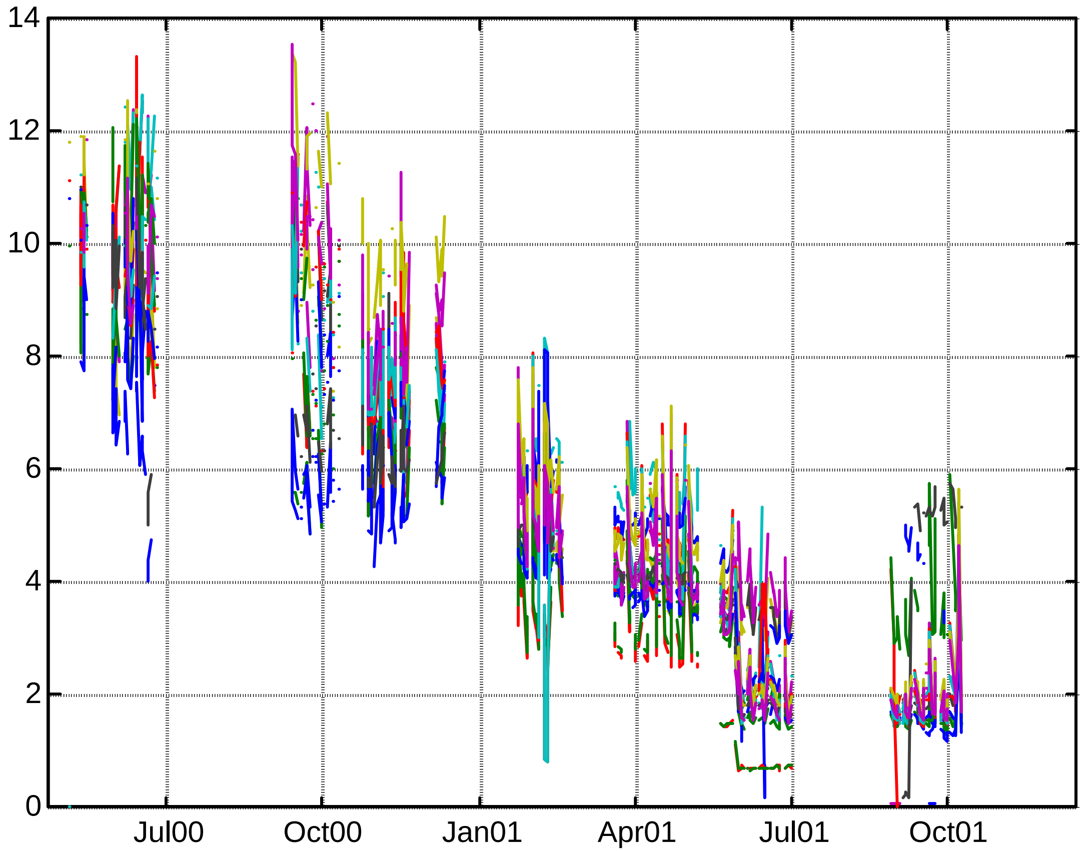




	PSD_{pk}		$rms_{4\text{-}12Hz}$	
	µm²/Hz	*ratio*	µm	*ratio*
noDL	158		11.7	
DL	3.2	49	3.1	3.8

e-beam motion

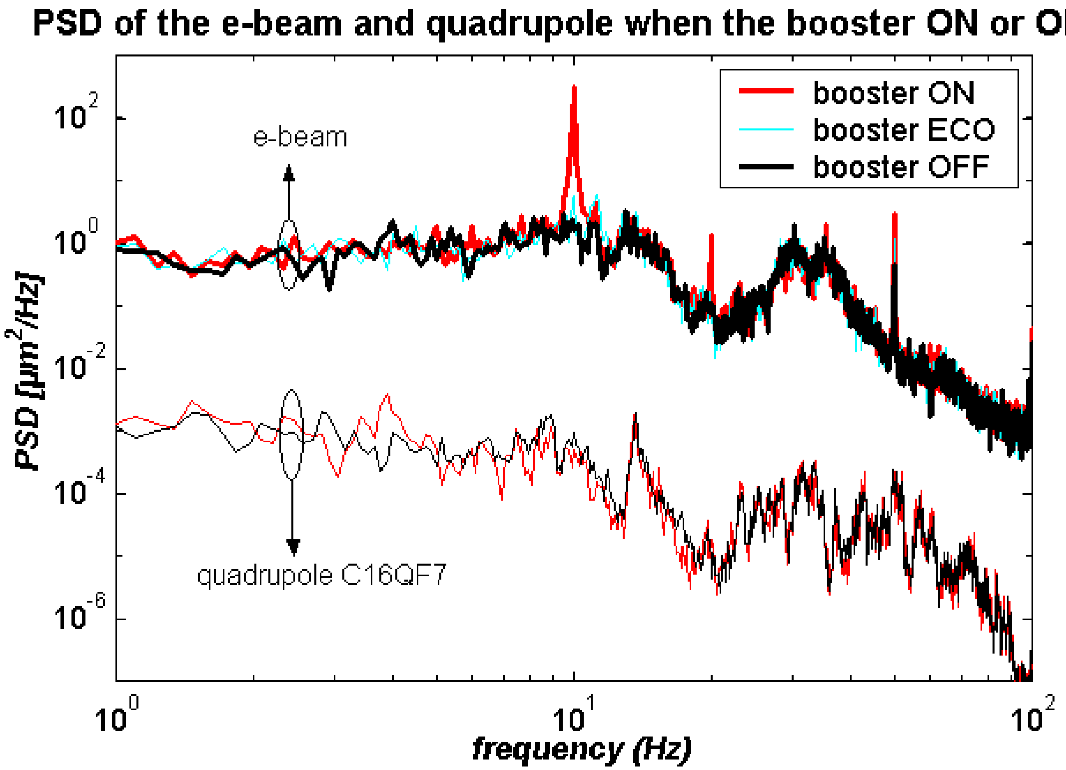
RMS amplitude (μm) of the horizontal motion in the frequency range of 4-12 Hz



The RMS amplitude was reduced from

- **10 μm to 2.7 μm (4-12 Hz)**
- **12 μm to 4 μm (4-200 Hz)**

e-beam motion



the operation of the booster :

- *during the weekly day of Machine Dedicated Time (MDT)*
- *around re-injection time*

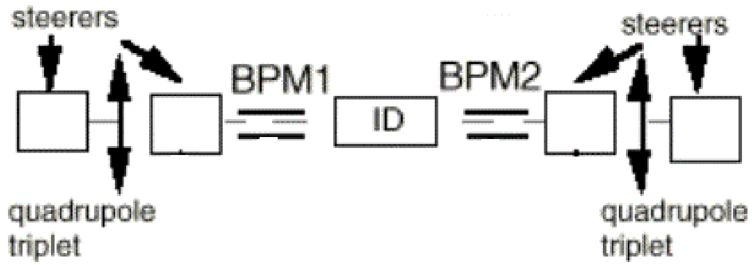
the ESRF booster is

a 10 Hz fast cycling synchrotron

$$ratio = \frac{PSD_{e-beam}}{PSD_{quadrupole}} \approx 1000 \quad \longrightarrow \quad \frac{RMS_{e-beam}}{RMS_{quadrupole}} \approx 30$$

e-beam feedback

- **Global feedback**
  - Vertical : 16 BPMs and 16 correctors
  - *Horizontal : 32 BPMs and 24 correctors (to be implemented)*
- **Local feedback** (for Horizontal direction)
  - installed on 4 straight sections
  - 4 steerers + 2 BPMs / bump
  - correction rate : 4.4 KHz
  - Bandwidth : 0.01 to 100 Hz



e-beam motion - *summary*

at the middle of a high-β straight section (β_x = 35.4 m)

RMS $_{horizontal}$ = 402 μm

ΔRMS $_{horizontal}$ (μm)	4-12 Hz	4-200 Hz
no damping links (μm)	10	12
with damping links (μm)	2.7	4
damping links + feedback (μm)	0.28	1

6 μm (low-β)
40 μm (high-β)

at the middle of a high-β straight section (β_z = 2,5 m)

RMS $_{vertical}$ = 8 μm

ΔRMS $_{vertical}$ (μm)	4-12 Hz	4-200 Hz
with damping links (μm) (μm)	0.5	1
damping links+feedback (μm)	0.17	0.6

0.8 μm

End

Thank you

For your attention