Strategy for SOLEIL Beam position Stability

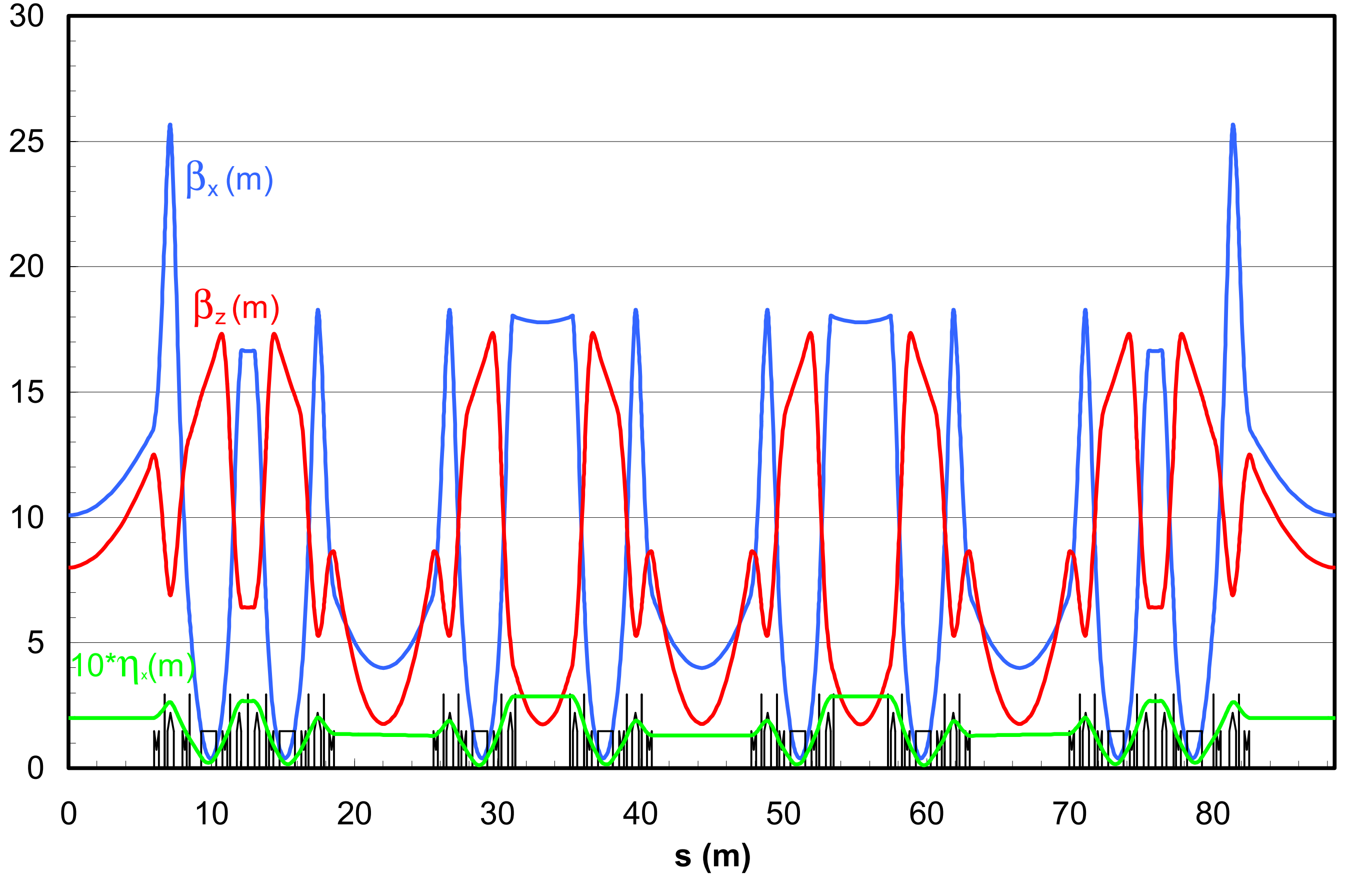
M. P. LEVEL on behalf of the SOLEIL team

- Parameters of the Storage ring
- Orbit correction scheme
- Stability criteria
- Foundations:
  - APD solution
  - Vibration measurement campaigns
  - New foundations solution
- Strategy for the SR:
  - Medium and short term stability
  - Slow feedback, fast feedback and feed-forward compensation

STORAGE RING

Energy:	*2.75 GeV*
Circumference:	*354.097m*
Emittance (rms):	*3.70 nmrad*
Number of cells / super periods:	*16 / 4*
Straight sections:	*12m x 4 ; 7 m x 12 ; 3.8 m x 8*
Betatron tunes, Q_x/Q_y:	*18.2 / 10.3*
Natural Chromat. ξ_x/ξ_y :	*- 2.88/-2.21*
Momentum compaction:	4.49×10^{-4}
Energy dispersion	$1.02\ 10^{-3}$

STORAGE RING



Lattice and optical functions for a super period of the storage ring

Orbit Correction Scheme

- BPMs distribution:

120 located close to the Quad. or Sext. and Straight S.

- Closed Orbit Distortion:

56 girders of 3 types

Standard alignment errors ⇒COD max : 15 mm (H), 7 mm (V)

- Closed Orbit Correction: 120 possible correctors in Sext.

SVD method: 56 eigenvalues in H and V planes

Minimal configuration: 56 correctors in H and V planes

H plane: Max. value=500µm, always in the BMs (will be improved after magnetic meas.)
Straight sections: r.m.s. = 25 µm and maximum 100 µm

V plane: Max. value=150µm, always in the BMs
Straight sections: r.m.s. =15 µm and maximum 100 µm

Correctors Strengths and resolution

✓taking into account BPM displacement errors of 100µm – r.m.s. and output accuracy of 0.2 µm – r.m.s.

	Horizontal plane	Vertical plane
Maxium rms value	0.133mrad	0.0937mrad
Maximum value	**0.401mrad**	**0.238mrad**

Remark: BPM position error will be reduced to 50 µm r.m.s. by B.B. A.

✓It was decided to take a factor 2 margin and to design the maximum corrector deflexion at **0.8 mrad.**

✓**The resolution is not completely decided between 18 and 20 bits**

(We must also take into account the noise induced by SVD algorithm)

Beam Position Stability

Different noise sources with 3 different time scales:

- Long term stability: differential settlement and temperature variation with seasons ⇒ Building foundations

- Medium term stability: in general thermal drifts ⇒ vacuum chamber, water cooling, air conditioning etc

- Short term stability :
  - random in-situ sources of vibrations surrounding the machine site, such as:human activities, mechanical devices, water cooling,…
  - external source of vibration generating plane waves propagating in the ground.

Beam Position Stability Requirements

- The detrimental effect of beam position instabilities can be seen as a macroscopic increased emittance.

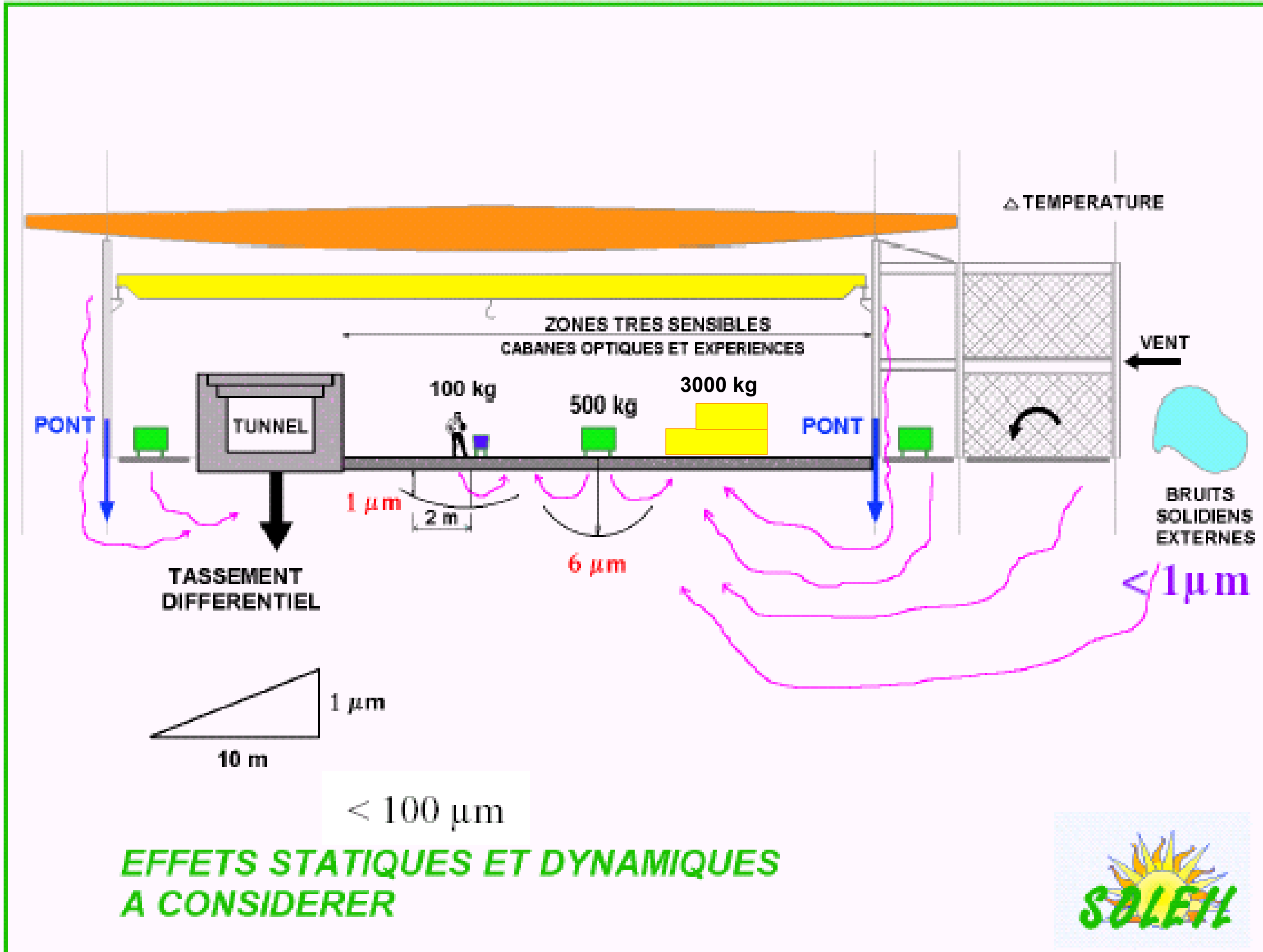
Following the users specification we take:

$$\sigma_{COD} < 0.1\,\sigma_{Beam} \text{ and } \sigma'_{COD} < 0.1\,\sigma'_{Beam}$$

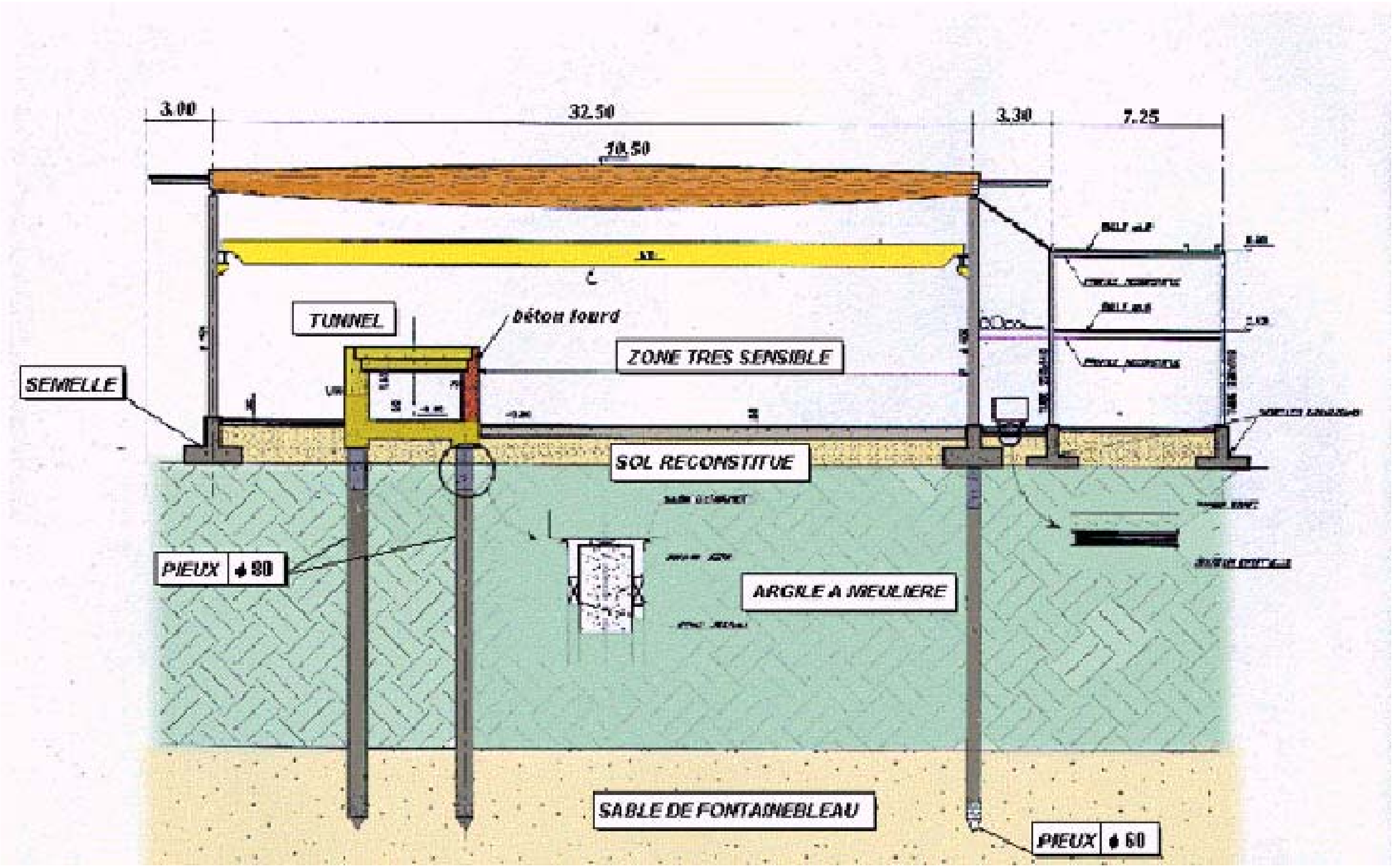
	σ_{COD} (μm)	σ'_{COD} (μrad)
Horizontal	18	3
Vertical	0.8	0.5

In the most stringent case this correspond to $\Delta\varepsilon/\varepsilon$ = 1%

Building foundations: Design criteria



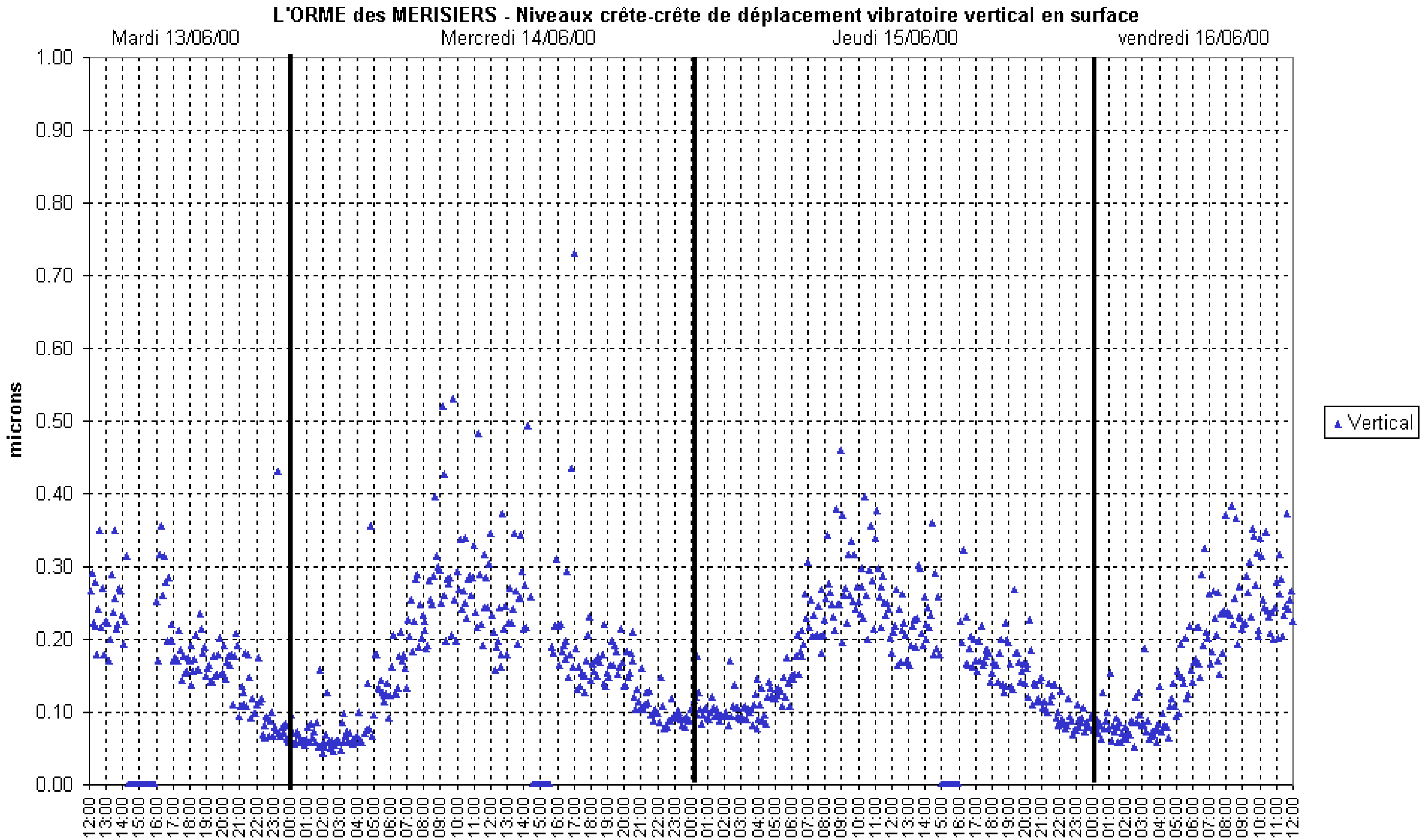
Building foundations: APD98 solution



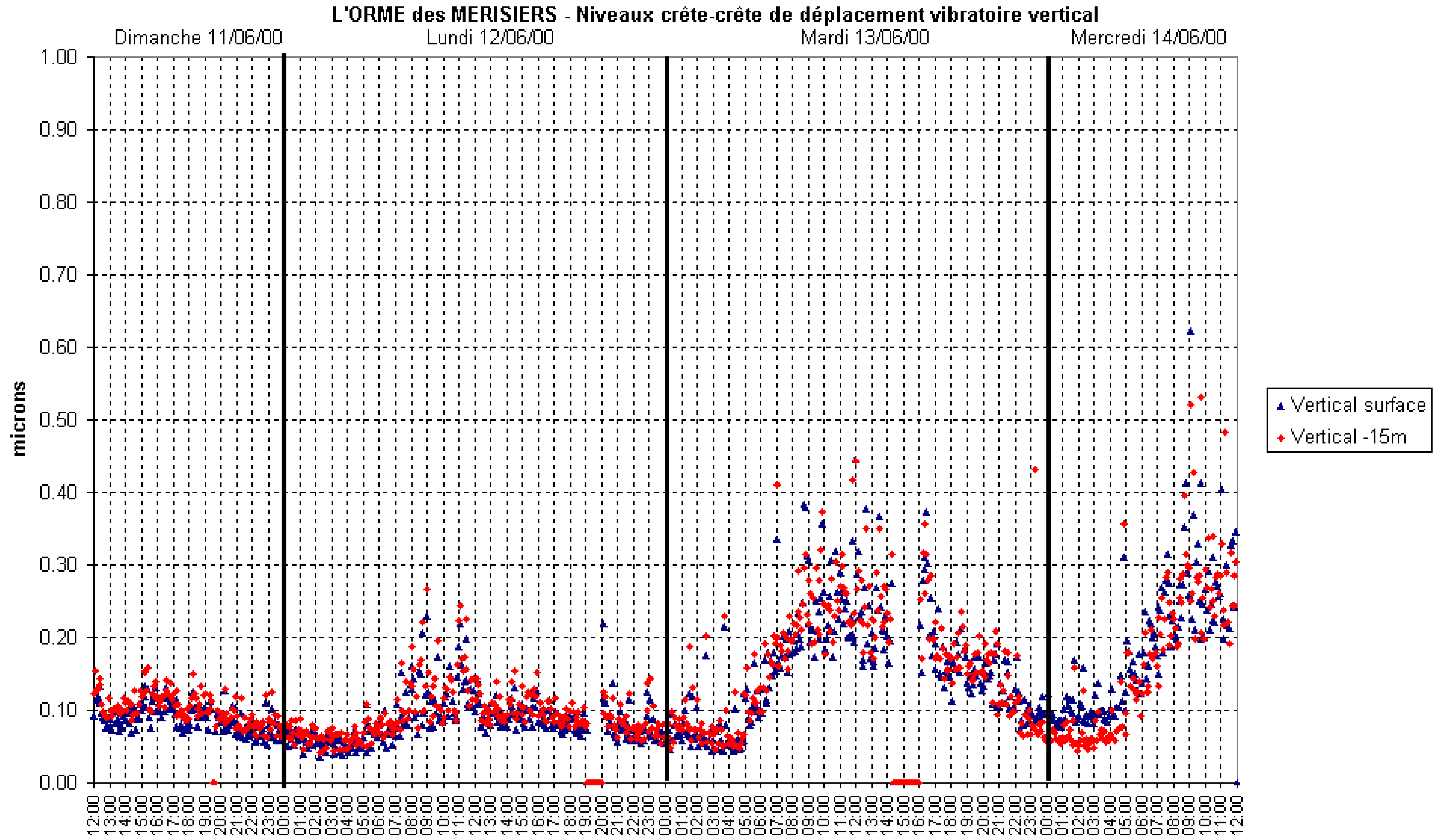
- Solution APD 98, reservations about:
  - Elastomer supports: *behaviour with time? No possibility to inspect it.*
  - The differential settlement between the ring tunnel and experimental hall slab: *it should be gone beyond the deformation criteria (>100 microns/year during 10 years) due to the swelling effect of silt and clay*
  - The justification of the advantage of the piles with sleeving

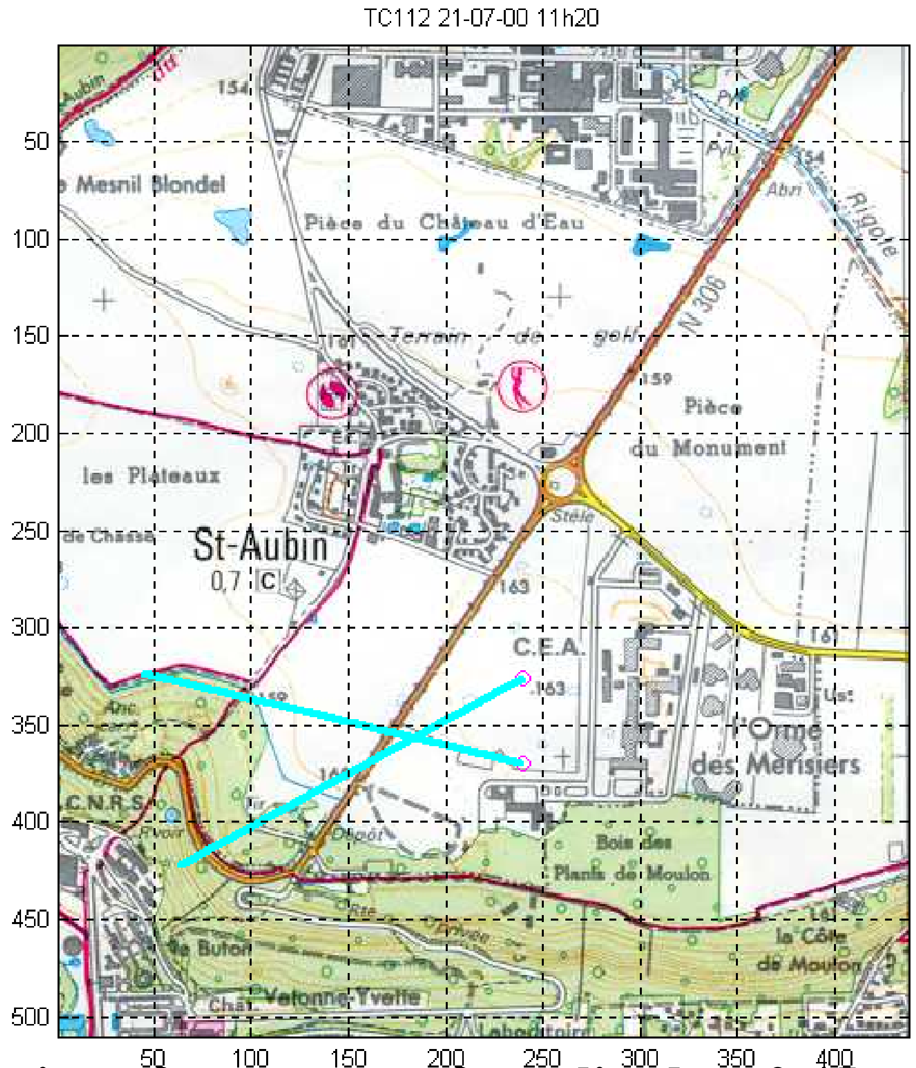
Vibration measurement campains

- 3 campaigns of vibrations measurements coming from the site environment showed:
  - Sinusoidal noise with in the daytime a maximum elongation peak to peak of 0.35 μm + some accidents of 0.5 – 0.7 μm (planar wave 2.5 Hz)
  - same amplitude level at the ground level and –15m deep at the Fontainebleau sands level.
  - The accidents have been identified as waves produced by some kind of public work trucks in correlation with some kind of irregularities of the two adjacent roads

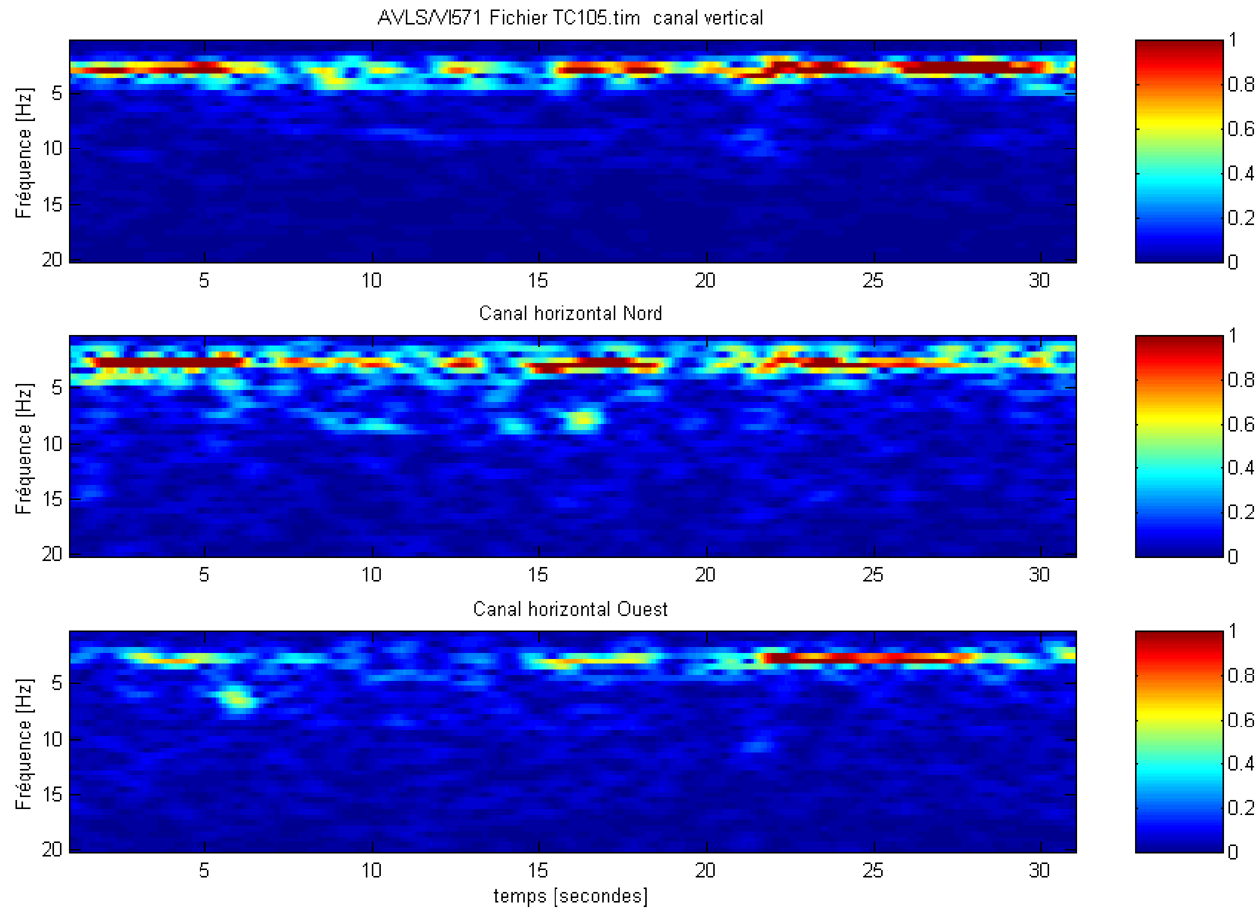


L'ORME des MERISIERS - Niveaux crête-crête de déplacement vibratoire vertical en surface
Mardi 13/06/00
Mercredi 14/06/00
Jeudi 15/06/00
vendredi 16/06/00
microns
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Vertical


L'ORME des MERISIERS - Niveaux crête-crête de déplacement vibratoire vertical
Dimanche 11/06/00
Lundi 12/06/00
Mardi 13/06/00
Mercredi 14/06/00
microns
Vertical surface
Vertical -15m



Exemple of localization of one event of amplitude > 0.45 microns peak to peak



We notice that the lorry produces essentially a frequency of 2.5 Hz (0.57 micron peak to peak)

The confirmation of these results have been realized by organising night traffics of 4 different types of heavy trucks on the roads lining the site:

⇒The importance of the vibratory levels reached is not only linked to the trucks weight but essentially depends on the closeness of the two frequencies: the truck suspension resonance frequency and the typical frequency of the ground, of the order of 2.5 Hz.

⇒Another factor plays a part: the longitudinal profile which properties favour the vibratory exitations in the particular frequency range : The average truck speed being of 60 km/h, the most unfavorable road defect is the one that generates an excitation of 2.5 Hz, which corresponds to a 3 meter long basin

⇒ *Led to plan a repairs of the roadway. The maintenance of the quality of their surface in the time will be necessary to get us rid of these vibrations.*

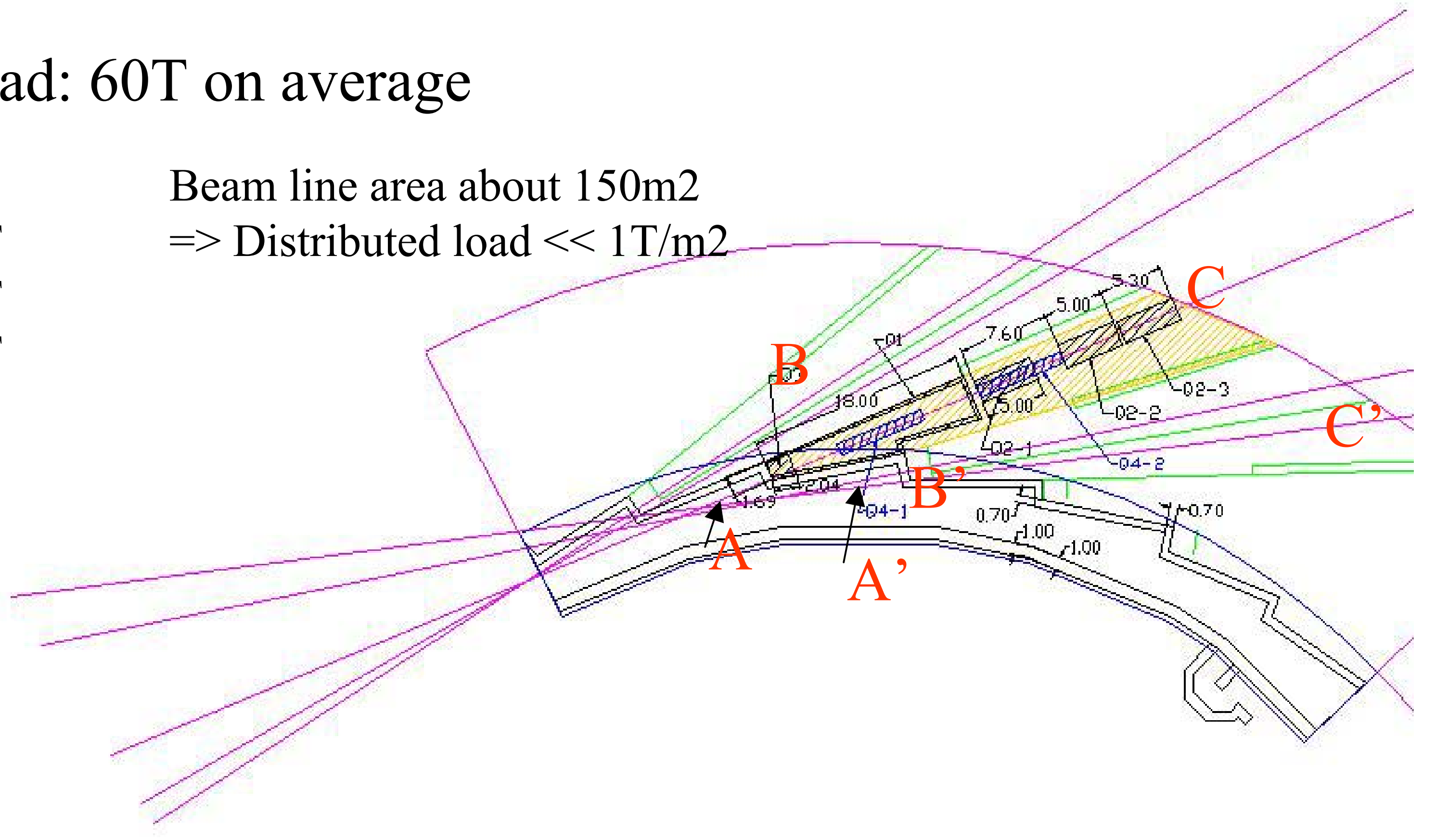
⇒ *Set again the question about the interest of the double sleeving of the piles bearing the slab of the storage ring tunnel.*

Design of beam line loading

global load: 60T on average

Q3=3T
Q4=15T
Q1=25T
Q2=15T

Beam line area about 150m2
=> Distributed load << 1T/m2



⇒ Solution of APD98 cannot reach criteria on this site.

⇒ 2 families of solutions studied :

- Bored piles under the slabs of the ring tunnel and experimental hall:
  - with double sleeving
  - without sleeving
- Compacted soil (continuous slab put directly on it):
  - Substitution of a part of the silt by a sand-gravel-cement mixture (3m height)

⇒ Analysis of the static behaviour:

-the intrinsic weight (slab and local storage ring tunnel, slab of the experimental hall)

-the load (addition of the load due to a beam line installation)

- The two kinds of solutions enable to respect the criteria with the « noble » area (experimental slab, ring, booster and linac)

- In a budget point of view the solution piles without sleeving is by far the best one :

  soil reconstructed solution : +3M€ vs the APD 98 solution

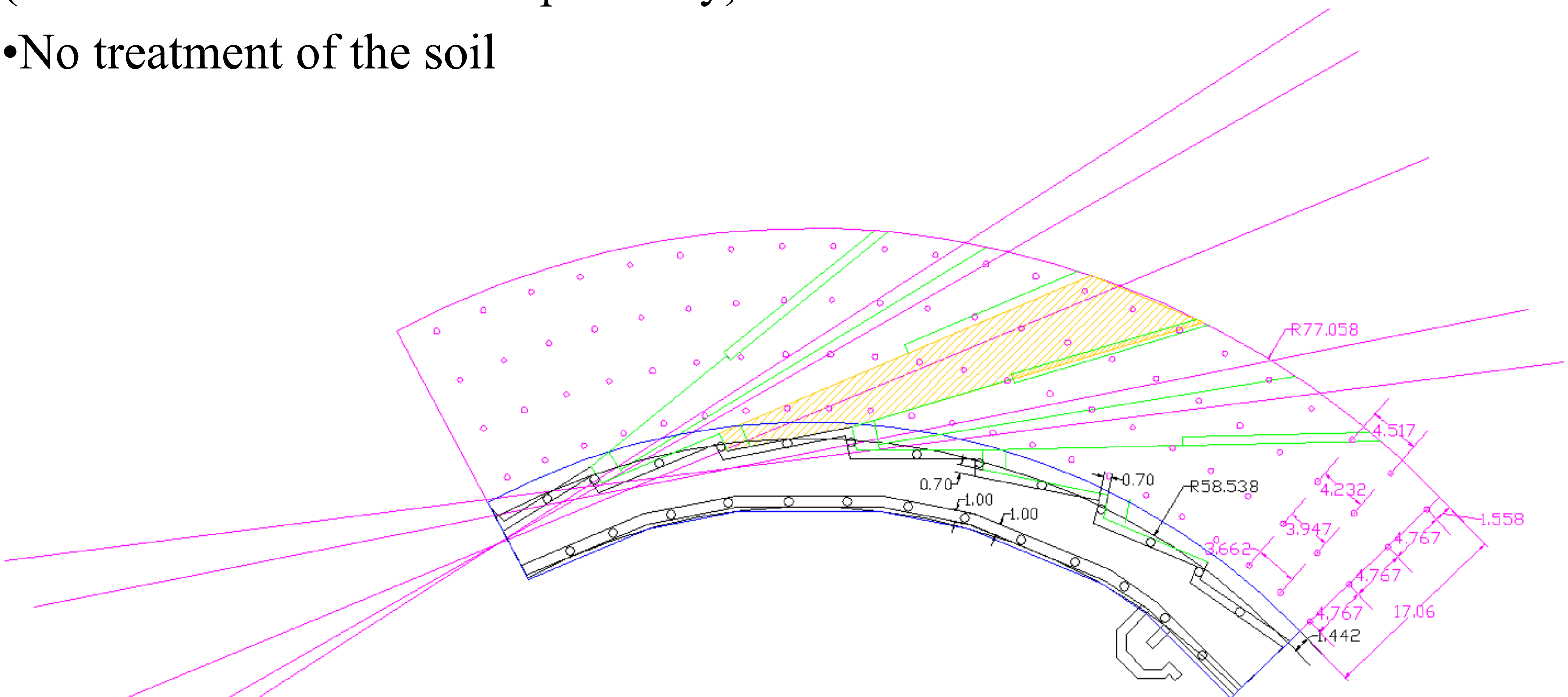
  solution piles with sleeving: +4.6M€

  solution piles without sleeving : +1.2M€

Chosen solution: bored piles

•Slab (0.8m thick) of the ring tunnel and experimental hall on simple bored piles (diameter 0.8 and 0.6m respectively) *with connected slab*

•No treatment of the soil



420 under the experimental hall (4*105)

128 under the ring tunnel

64 under linac and booster with a slab unconnected

Static deformation results

- No differential settlement between the ring tunnel and experimental hall.
- When a new beam line is installed: the criteria are respected:

	Displacement (µm)		
Location	**immediately**	**after 6 months**	**total**
A ring	**4**	**8**	**10**
A' ring	**13**	**27**	**35**
B beam line	**15**	**31**	**40**
C beam line	**41**	**55**	**110**
Maxi under beam line	**58**	**120**	**155**
B' neighbouring b.l.	**19**	**39**	**50**
C' neighbouring b.l			**0**

New Building foundations solution

⇒Dynamic studies

–Software SASSI: impedance of piles (stiffness, damping)

–Software ANSYS: answer of a structure to a dynamic request (piles simulated by 3 springs)

•The ground shows an amplification at 2.5 ; 5 ;9 and 12 Hz

•The structure presents an amplification at 15 Hz

•The simulation of a propagating wave (same characteristics as those measured at the center of the ring) 2.5 Hz; amplitude 0.7 µm peak to peak ⇒ *slab displacement:* 0.78 µm peak to peak ⇒ *no amplification by the slab*

Strategy for the Storage Ring

Medium term stability: in general thermal drifts

- Space of 2 mm between magnetic elements and vacuum chamber.
- Air conditioning in the tunnel and water cooling : T = 21°C (±0.1°). Air conditioning in the experimental hall : 21°C (±1°).
- BPM rigidly fixed on the girder with Thermal screen

SOLEIL SYNCHROTRON

Short time stability

Design of the girder

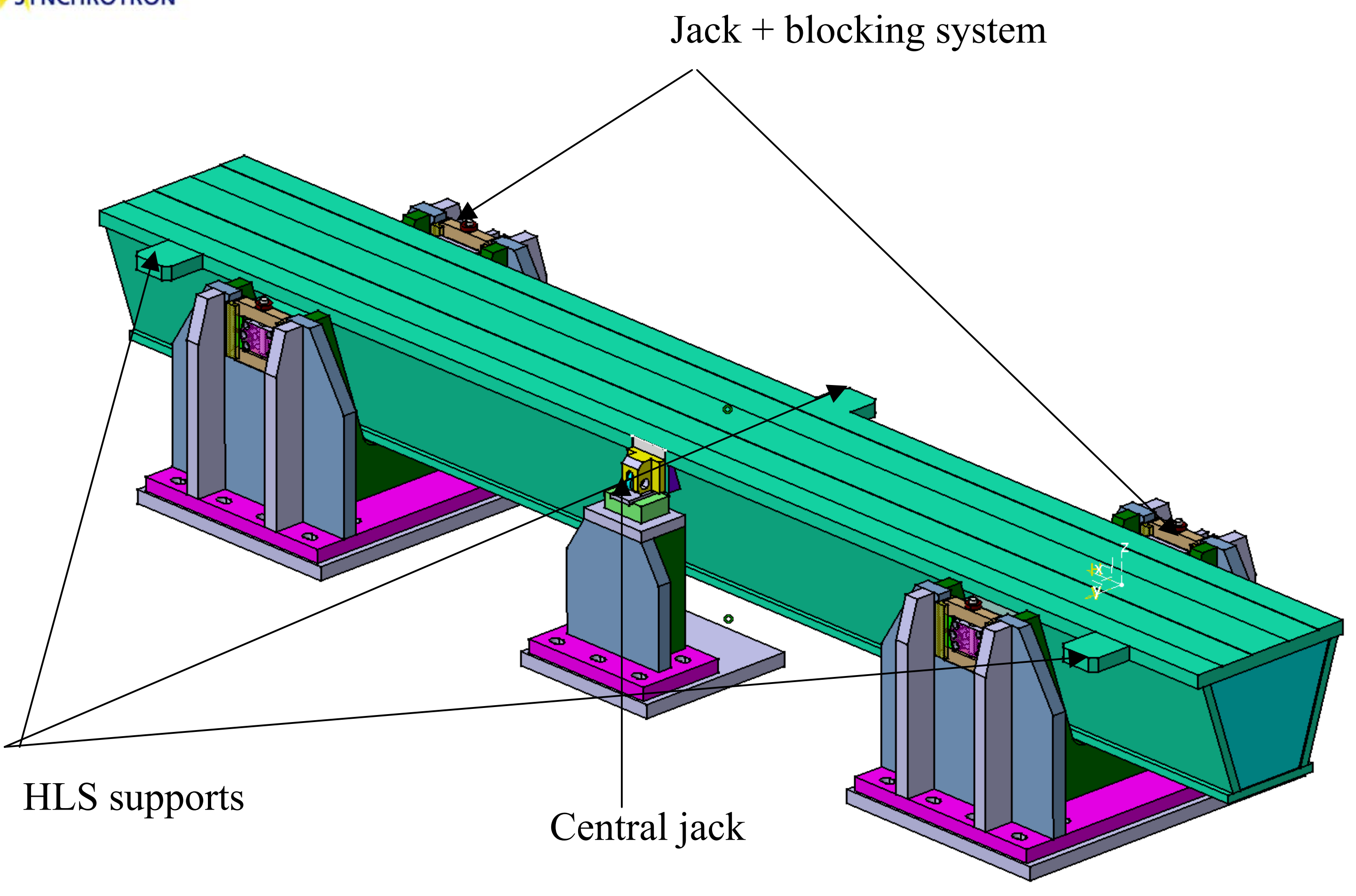
- Static: Alignment specifications

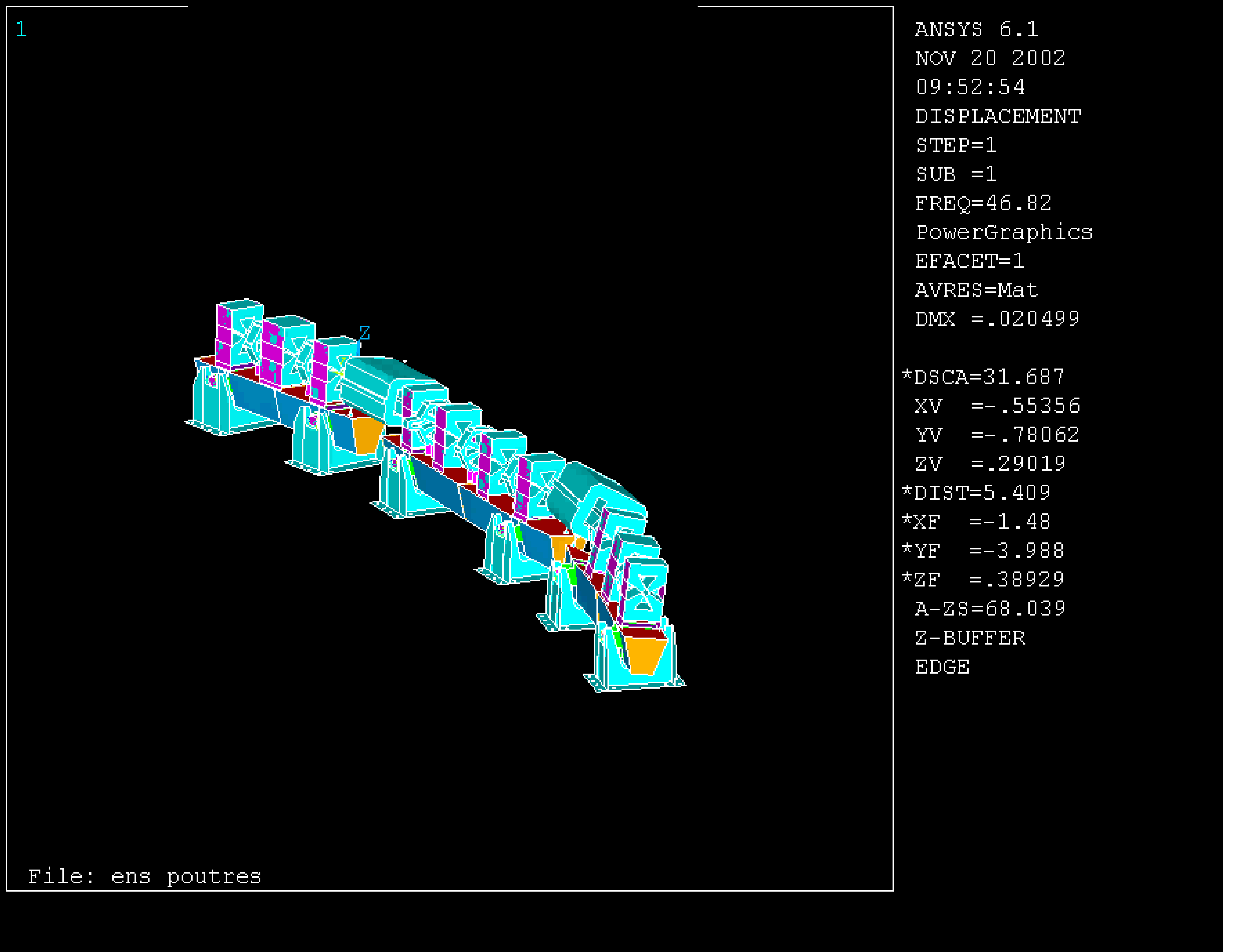
  HLS network

⇒3 jacks ; 4 supports all in the upper part of the girder

- Dynamic: Locking system ⇒high first resonance mode (42 Hz)

⇒No amplification of the propagating wave (0.78 µm peak to peak; 2.5 Hz) by the girder


Jack + blocking system
HLS supports
Central jack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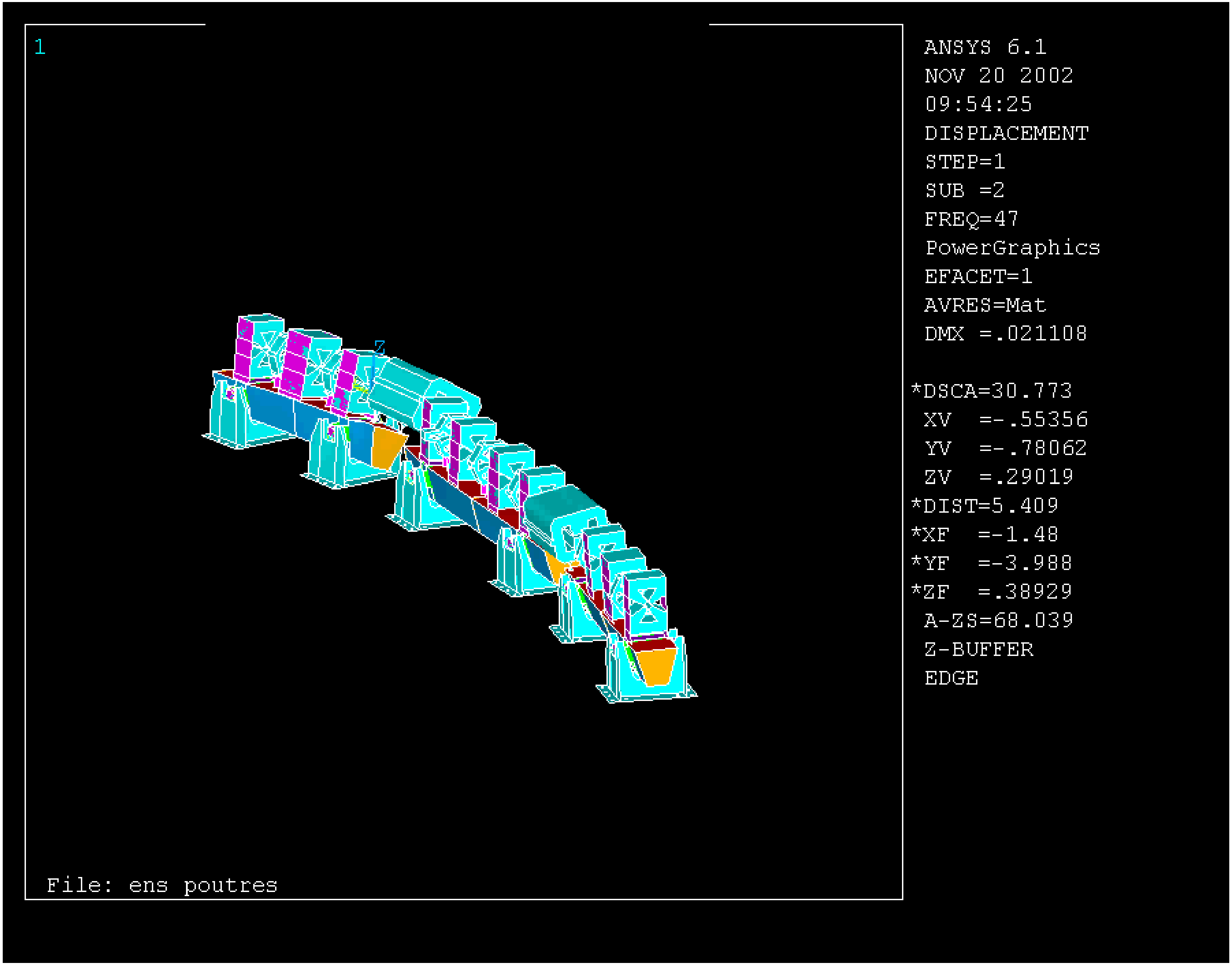
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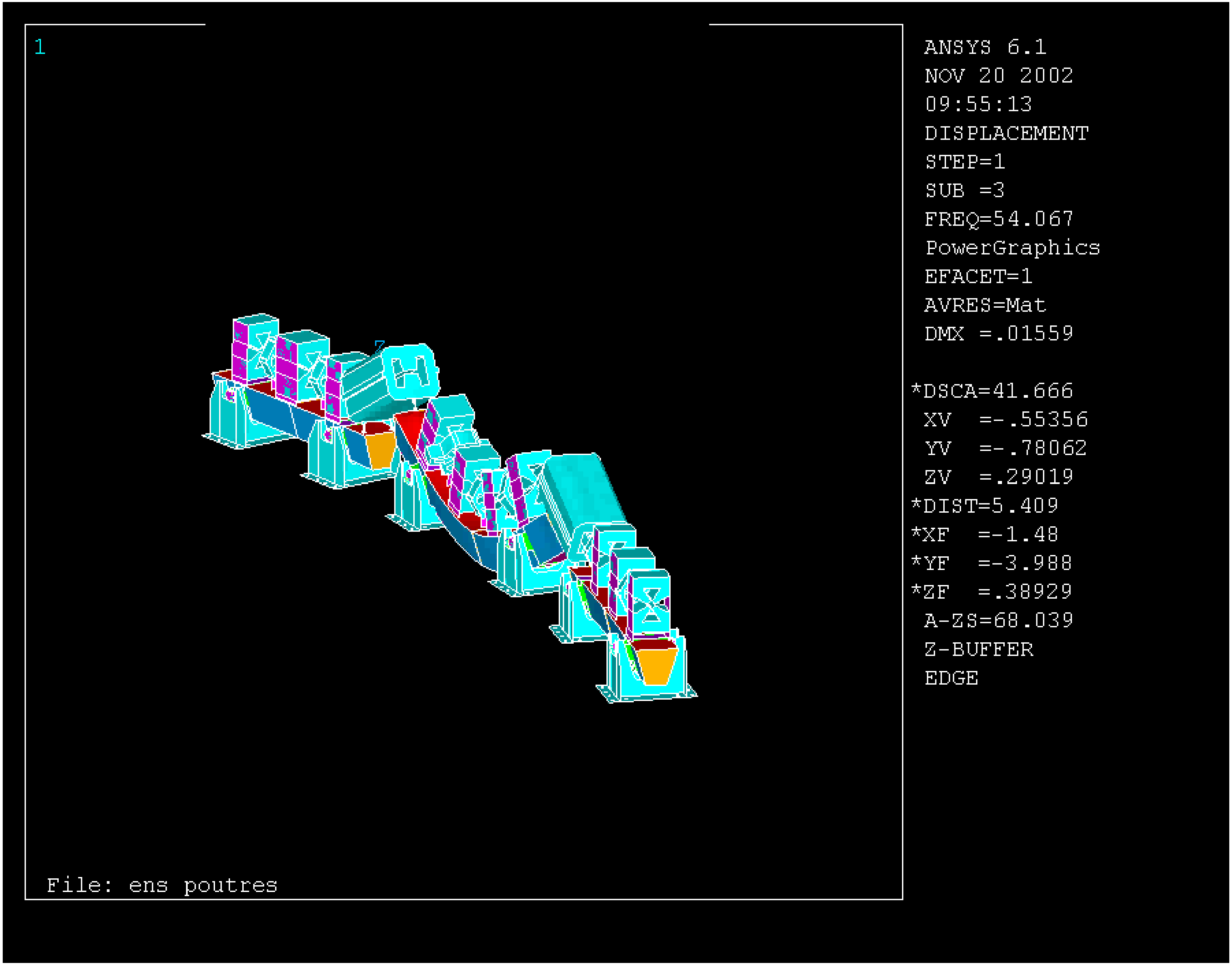
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A-ZS=68.039
Z-BUFFER
EDGE
File: ens poutres

Stability of the beam

$\sigma_{COD} < 0.1\,\sigma_{Beam}$ and $\sigma'_{COD} < 0.1\,\sigma'_{Beam} \Rightarrow$ **in the *most stringent* case**

tolerance for emittance growth: **$\Delta\varepsilon/\varepsilon$ +1%**

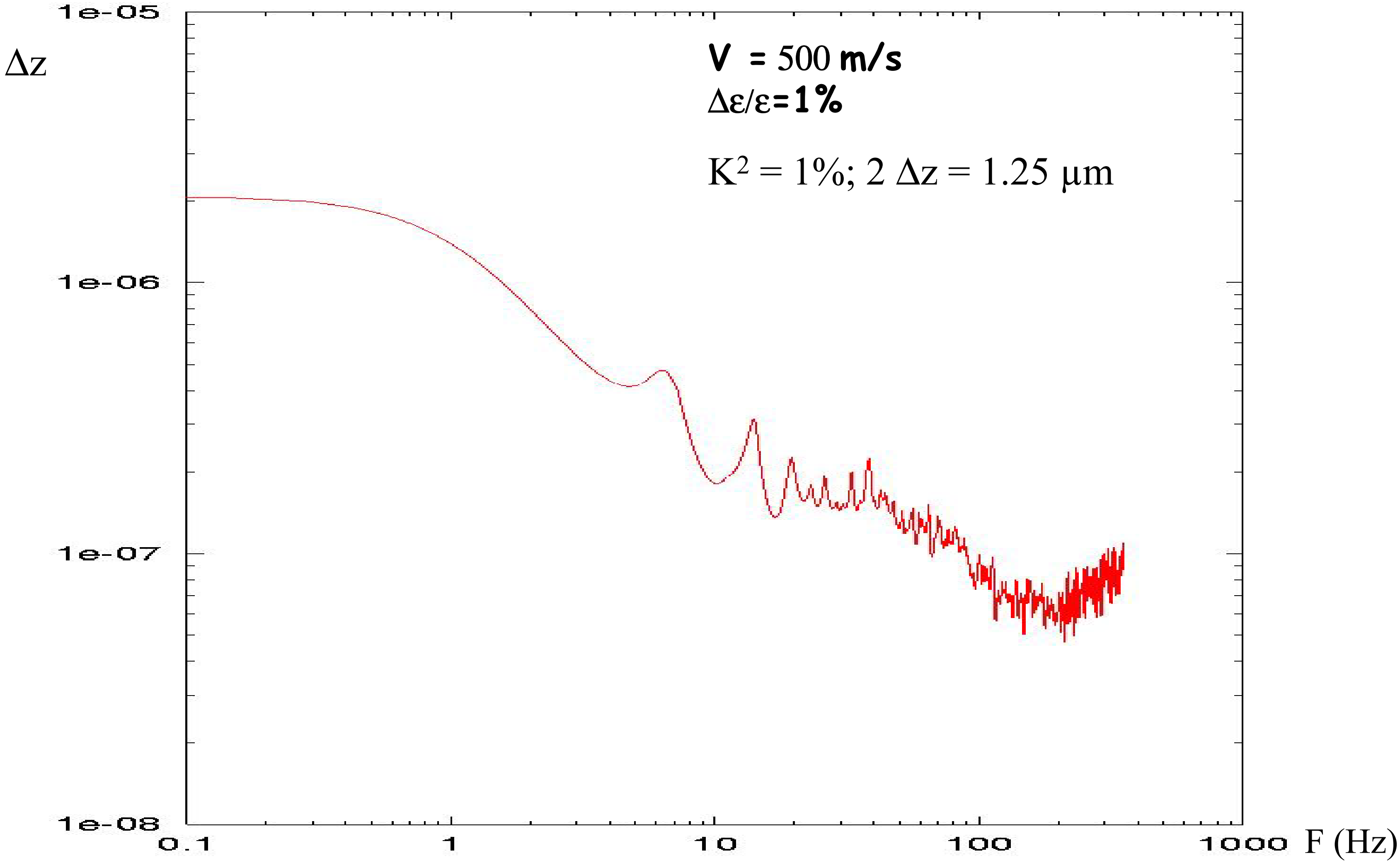
For an emittance coupling of 1% :

❖**Uncorrelated motion :** the r.m.s. values of the tolerances on the girders motion are 3.9 mm peak to peak and 1mm peak to peak respectively in the horizontal and the vertical plane.

❖**Correlated motion :** The tolerated vertical amplitude corresponding to 2.5Hz (*vibration measurements performed on the SOLEIL site)* is of 1.25 µm peak-to-peak which is above the amplitude of the cultural noise measured on the site (0.35 µm peak-to-peak, with some accidents at 0.7µm peak-to-peak).

Remark: for a coupling of 0.1% the tolerated vertical amplitude is 0.4 µm peak-to-peak, so it is necessary to suppress the accidents of higher amplitude

Vertical peak wave amplitude tolerated



Feedbacks

- Global slow feedback using 120 BPMs and 56 correctors in each planes H and V:
  - resolution 0.2 µm, correction every second (cf. J.C. Denard)
  - bandwidth 0 to 0.1 Hz
- Global fast feedback ⇒to stabilize all ID's experiments : 48 BPm's(among the 120 ones) and 48 correctors positionned on the bellows:
  - resolution 0.2 µm
  - Bandwidth 0.1 to 100 Hz
- Feed-forward compensation: Tables from magnetic measurements and experiments with beam applied on undulators correctors and possibly fast feedback correctors