OVERVIEW OF THE STATUS OF THE SOLEIL PROJECT

Content

- SOLEIL main characteristics
- Specificities and innovative aspects
- Commissioning progress
- Conclusions

Jean-Marc FILHOL
on behalf of the SOLEIL team

Acknowledgements

Commissioning team : A Nadji, JC Besson, P Brunelle, L Cassinari, ME Courpie, C Daveran,JC Denard, P Gros, C Herbeaux, JF Lamarre, MP Level, P Lebasque, A Lestrade, A Loulergue, A Madur, P Marchand, L Nadolski, R Nagaoka, B Pottin, JB Pruvost, F Ribero, MA. Tordeux

Operator team :R Cuoq, A Bence, P DaSilva, X Deletoille, D Pereira, G Roux, S Petit

Magnetism and Insertion Device group

RF Group, Linac Group, Diagnostic group

Vacuum group

Alignment group

Mechanical and engineering group : JL Marlats et al

Electronics and Computer Groups : P Betinelli, A Buteau et al.

Infrastructure group : P Eymard, S Mzah et al.

Safety group

SOLEIL Characteristics

- Electron energy : 2.75 GeV
- Extended spectral range :
  From UV (5 eV) up to hard X-Rays (15 KeV)
- 3rd generation => Many insertion device beamlines
  21 straight sections available (29% of ring circ.)
- High brilliance (10^{20}) in the soft X-ray range :
  => small emittance and high intensity
- Best achievable beam position stability

24 Beamlines

22 Beamlines approved by the Council + 2 beamlines to be defined:

16 on insertion devices and 6 on bending magnets

Spectral range equally shared :

50% below 1.3 keV and 50% above

Phase 1: 11 beamlines being built =>open to external Users in 2007

6 on insertion devices and 3 on bending magnets **+ 2 IR**

Phase 2: 7 beamlines open to external Users in 2008

5 on insertion devices and 2 on bending magnets

+ 4 beamlines on ID open to external Users in 2009

5 Straight sections still free + 15 bending magnet beamports !

Storage Ring parameters

Energy	2.75 GeV
Circumference	354 m
Number and length of straight sections	4 x 12 m 12 x 7 m 8 x 3.6 m
Horizontal emittance **Vertical emittance**	**3.7 10^{-9} m.rad** **37 10^{-12} m.rad**
Energy spread	1.16×10-3
Multibunch mode Lifetime	500 mA 18 h
8 bunch (30 ps every 148 ns) Lifetime (10% coupling)	90 mA 18 h

Storage Ring parameters

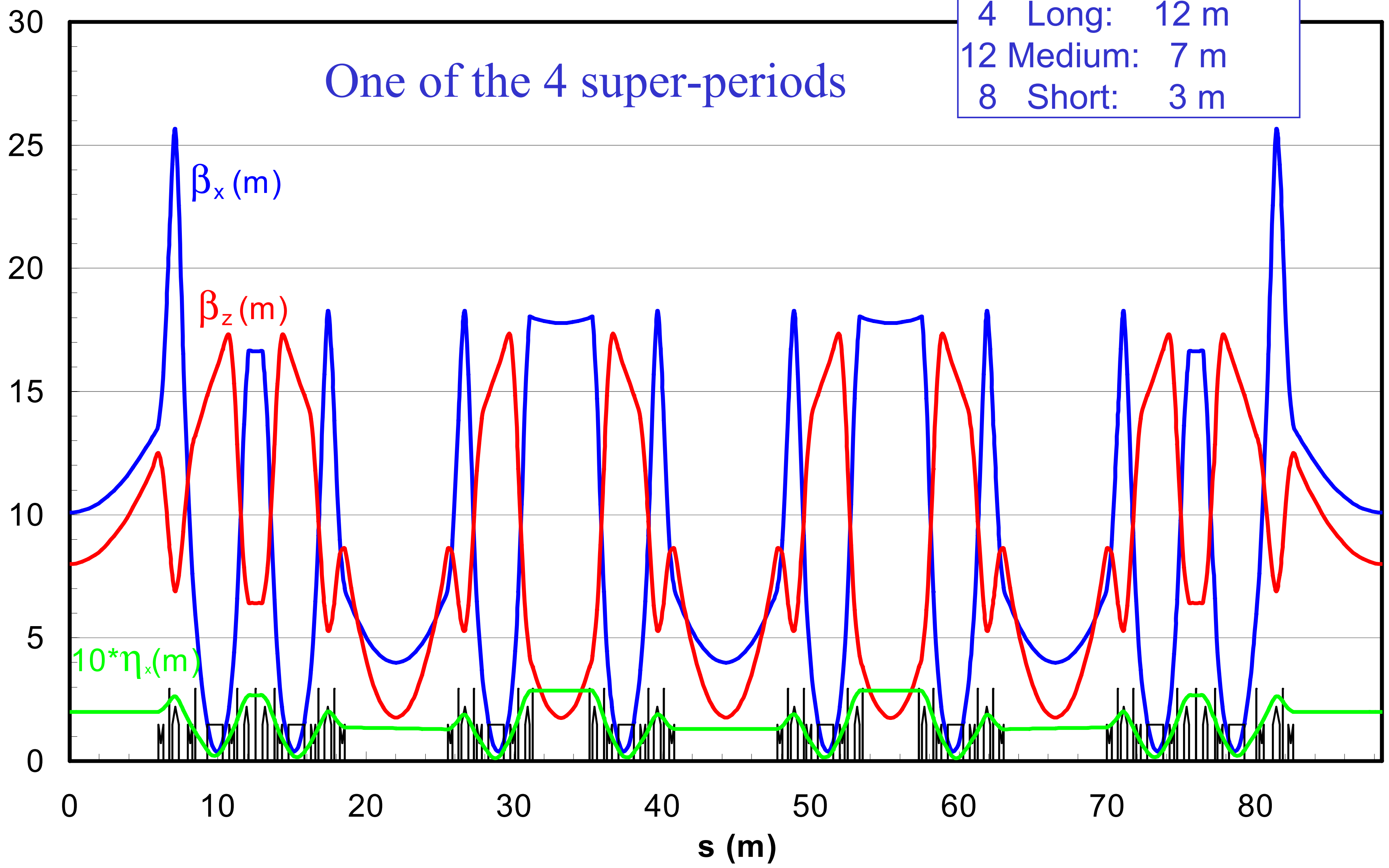
Horizontal tune Qx :	18.2
Vertical tune Qz :	10.3
Natural Chromaticities $\xi x/\xi z$:	-53/-23
Momentum compaction α_1 / α_2 :	$4.4\ 10^{-4}$ / $4.5\ 10^{-3}$

RF Frequency:	**352.202 MHz**
Harmonic number (max number of bunches)	**416**
Maximum RF Voltage:	4.8 MV
Energy loss per turn (with ID's):	1200 keV
Total radiation power loss (at 500 mA):	600 kW

Storage Ring Optical functions

24 Straight sections:

4 Long: 12 m
12 Medium: 7 m
8 Short: 3 m



Sizes and divergences at Source points

Horizontal emittance 3.7 nm.rad

	BetaX m	EtaX m	H Size **SigmaX µm**	H Divergence **Sigma XP µrad**	Effective Emittance H
Short straight	17,8	0,285	**388**	**14,5**	5,61 nm.rad
Medium straight	4,0	0,133	**182**	**30,5**	5,56 nm.rad
Long straight	10,1	0,200	**281**	**19,2**	5,40 nm.rad
Dipole 4°	0,38	0,021	**43**	**107,0**	

Vertical emittance 37 pm.rad (1% coupling)

	BetaZ m		V Size **SigmaZ µm**	V Divergence **SigmaZP µrad**
Short straight	1,75		**8,1**	**4,6**
Medium straight	1,77		**8,1**	**4,6**
Long straight	8,01		**17,3**	**2,2**
Dipole 4°	16,01		**24,5**	**2,1**

Search for the best stability

The requirement due to the vertical beam size is $\sigma/10 \sim 1\mu m$

⇒ Site and building aspects

⇒ Storage Ring Girder design

⇒ Keep constant the heat load on optical components:

=> Topping-up

- Linac
- Booster
- Storage Ring Injection equipments

Building design

Building were designed for optimum position stability :

All potential sources of vibrations in a separate technical building :
All pumps for different cooling circuits + supported on damping material
Compressor for the cryogenic source

Synchrotron building :
Storage Ring and Experimental Hall isolated from the other parts of the building

Exp. Hall :	=> Air temperature regulated at 21 °C ±1.0 °C
Storage Ring Tunnel :	=> Air temperature regulated at **21 °C ±0.1 °C**
	=> Water cooling circuit regulated at **21 °C ±0.1 °C**

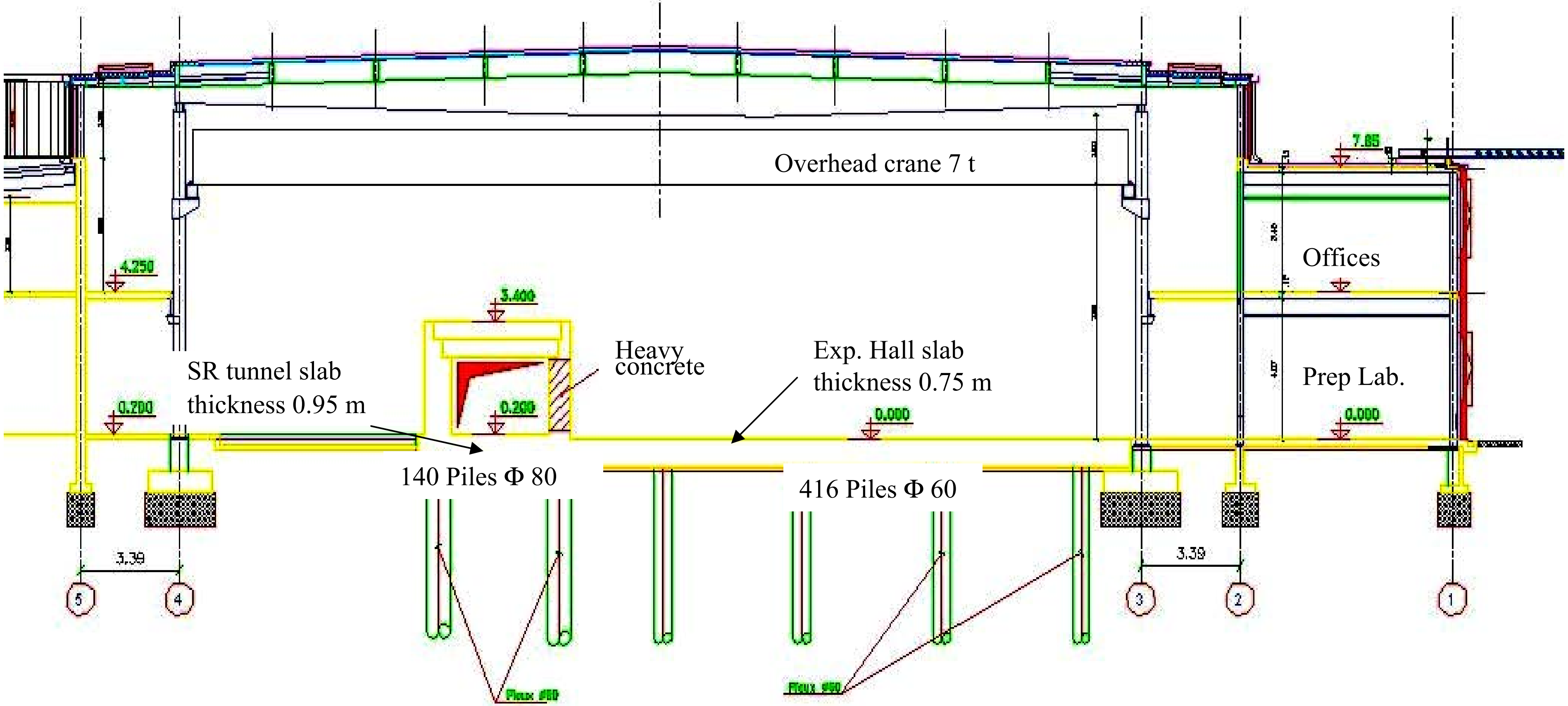
External perturbations
The surface of the 2 adjacent roads will be smoothen during this summer

Buildings


Technical buildings
Synchrotron building
Restaurant
Central building

Building design

95 cm thick slabs laying on piles for Storage Ring and Exp. Hall

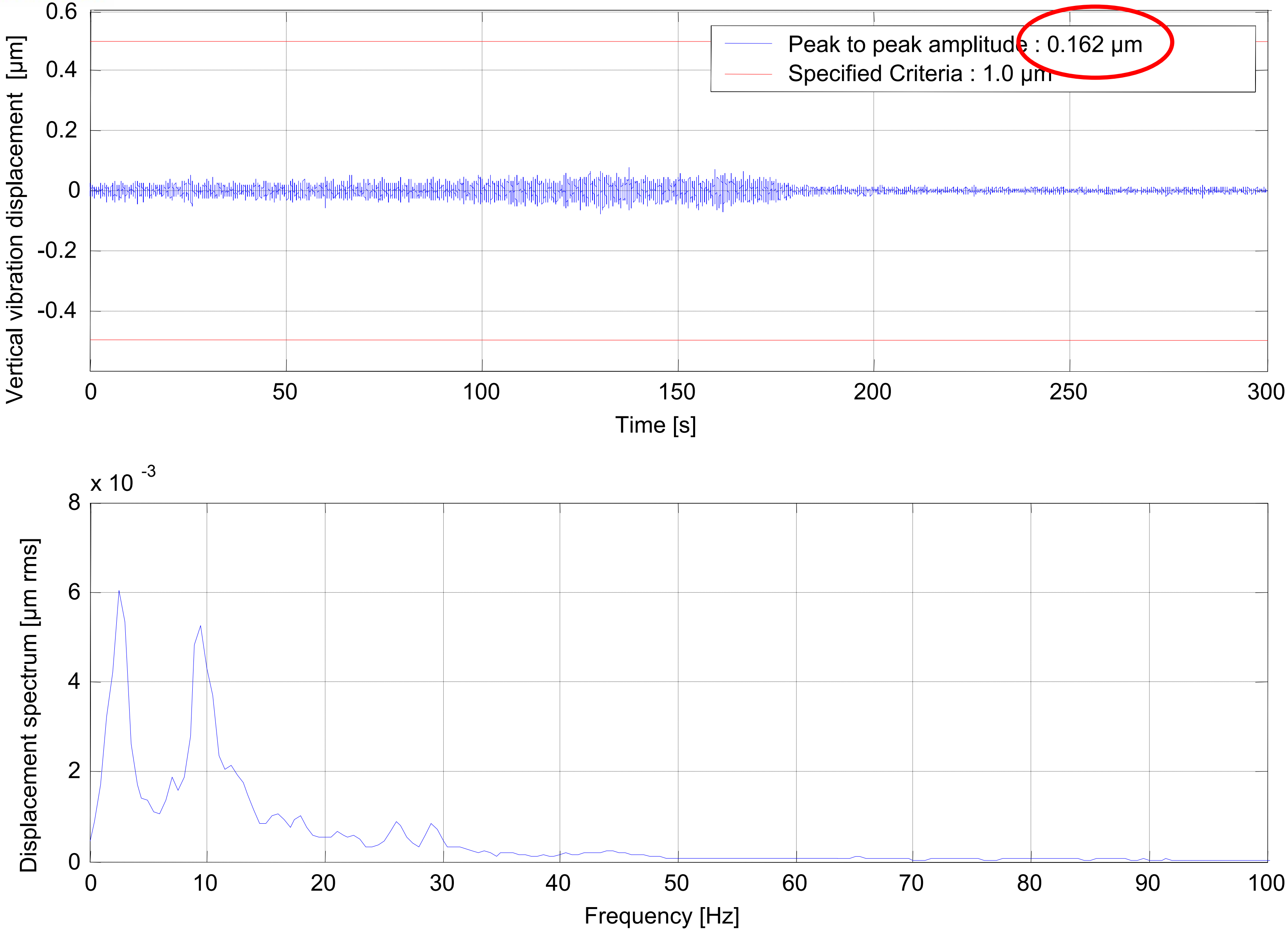


Slab settlement < 50 µm /year

Vibrations amplitude < ± 0.5 µm

Synchrotron building : Experimental Hall

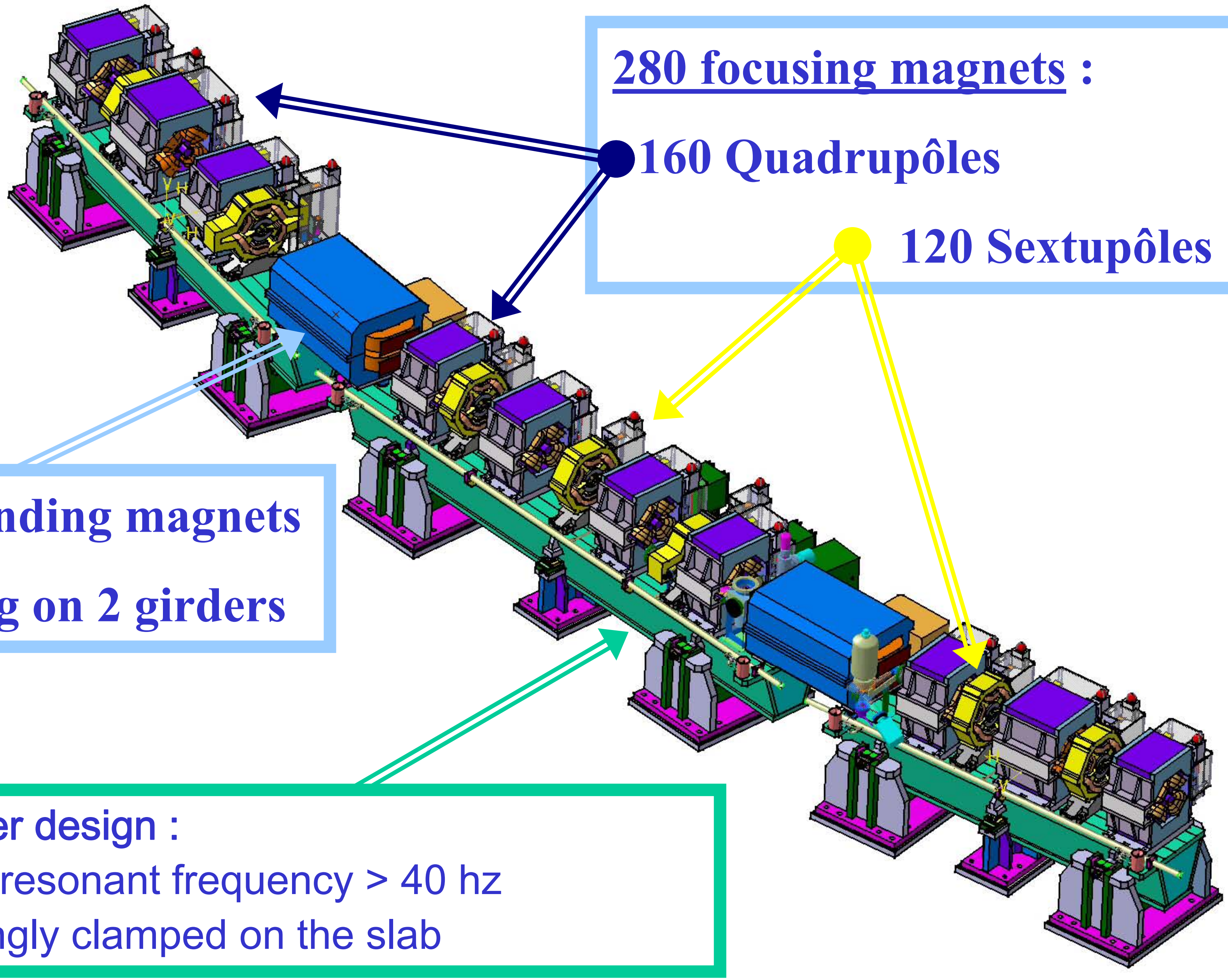
Vibrations measurements :
Effect of the crane on the storage ring slab



Search for the best stability

Storage Ring :

- Specific design of the girders supporting the magnets (1st eigen mode > 40 Hz)
- High resolution Beam Position Monitors (< 1 μm)
- Fast position feedback (1-100 Hz) implemented in 2007
- Minimize effects of ID gap changes (magnetic measurements)



280 focusing magnets :

160 Quadrupôles

120 Sextupôles

32 bending magnets

Sitting on 2 girders

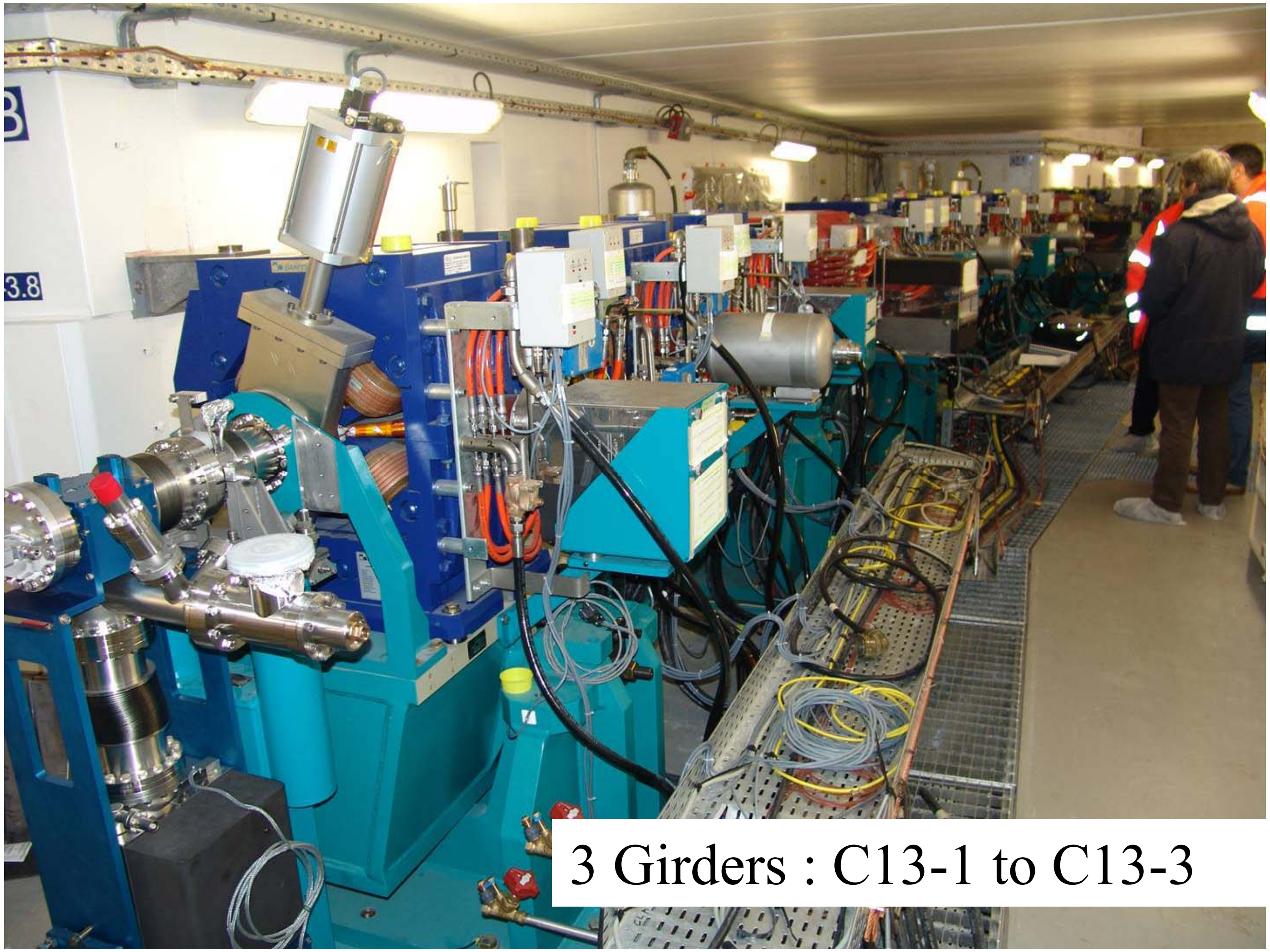
Girder design :

First resonant frequency > 40 hz

Strongly clamped on the slab

Vibration measurements on SR girders

Measurements done by AVLS company

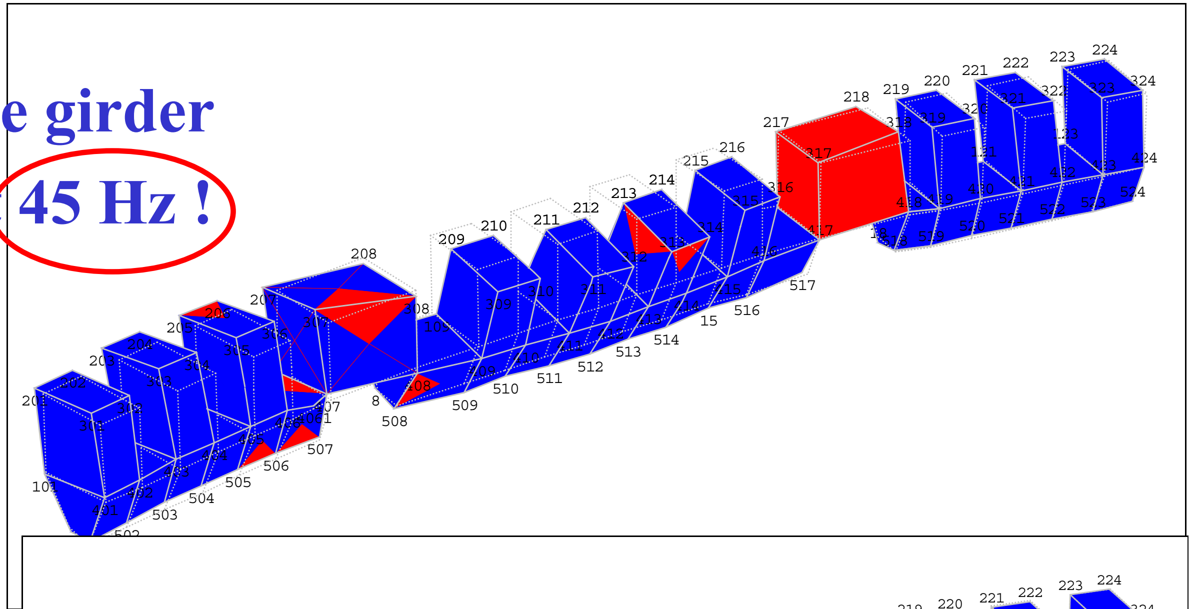


3 Girders : C13-1 to C13-3

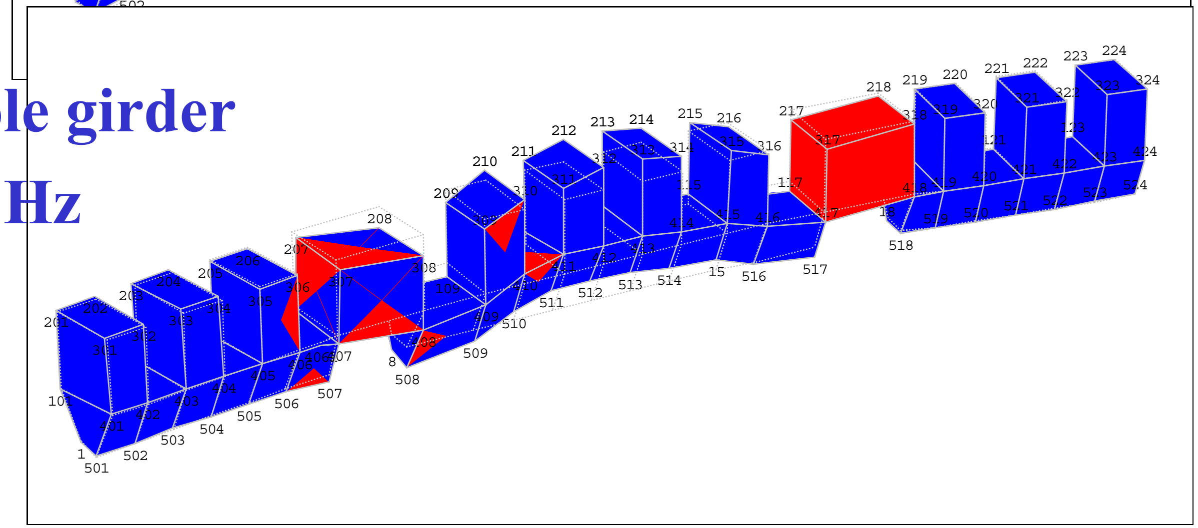
Vibration measurements on SR girders

Experimental Modal Analysis

1st mode on quadrupole girder (transversal flexion) at 45 Hz !

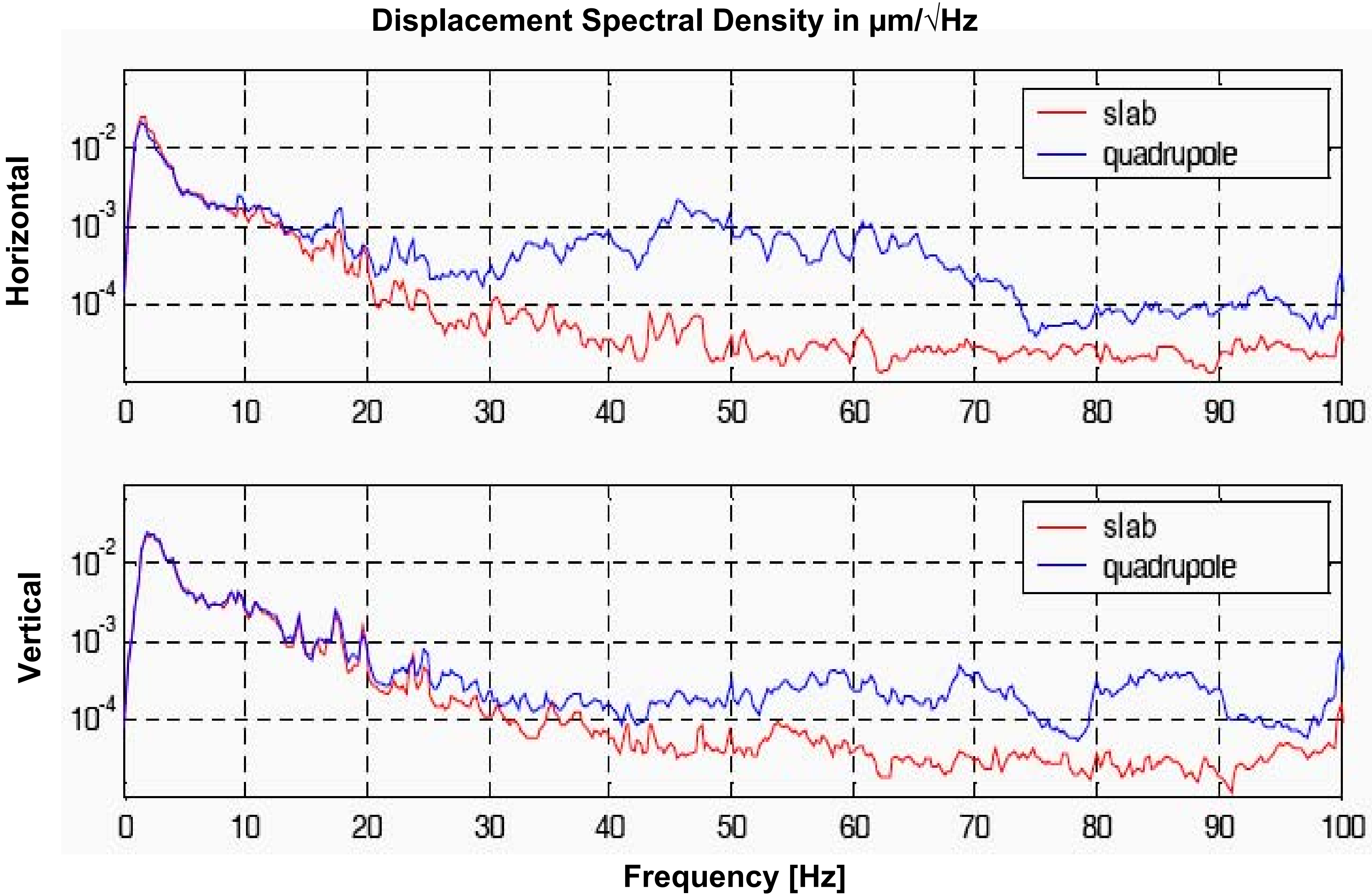


2nd mode on quadrupole girder (vertical flexion) at 56 Hz



Vibration measurements on SR girders

Residual levels with all utilities ON (cooling, ventilation,..)



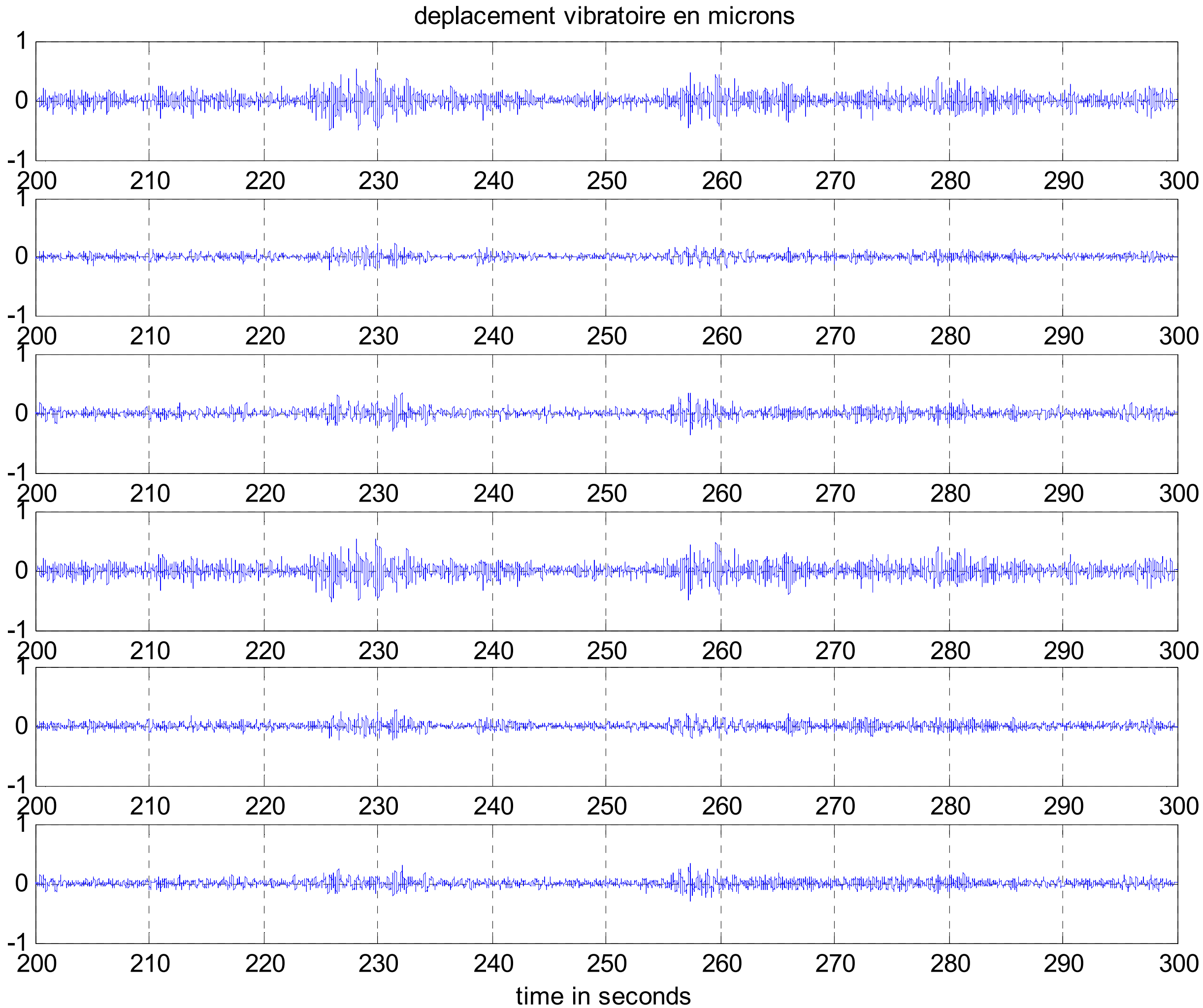
Vibration measurements on SR girders

with bulldozer + truck working on the site

Residual levels

Floor: Z (V), X, Y (H)

Top of quad C13-1: Z (V), X, Y (H)



Time Signals are very similar since there is no dynamic amplification in the 0-20 Hz range

Linac and Booster designed for topping-up operation

2.75 GeV BOOSTER

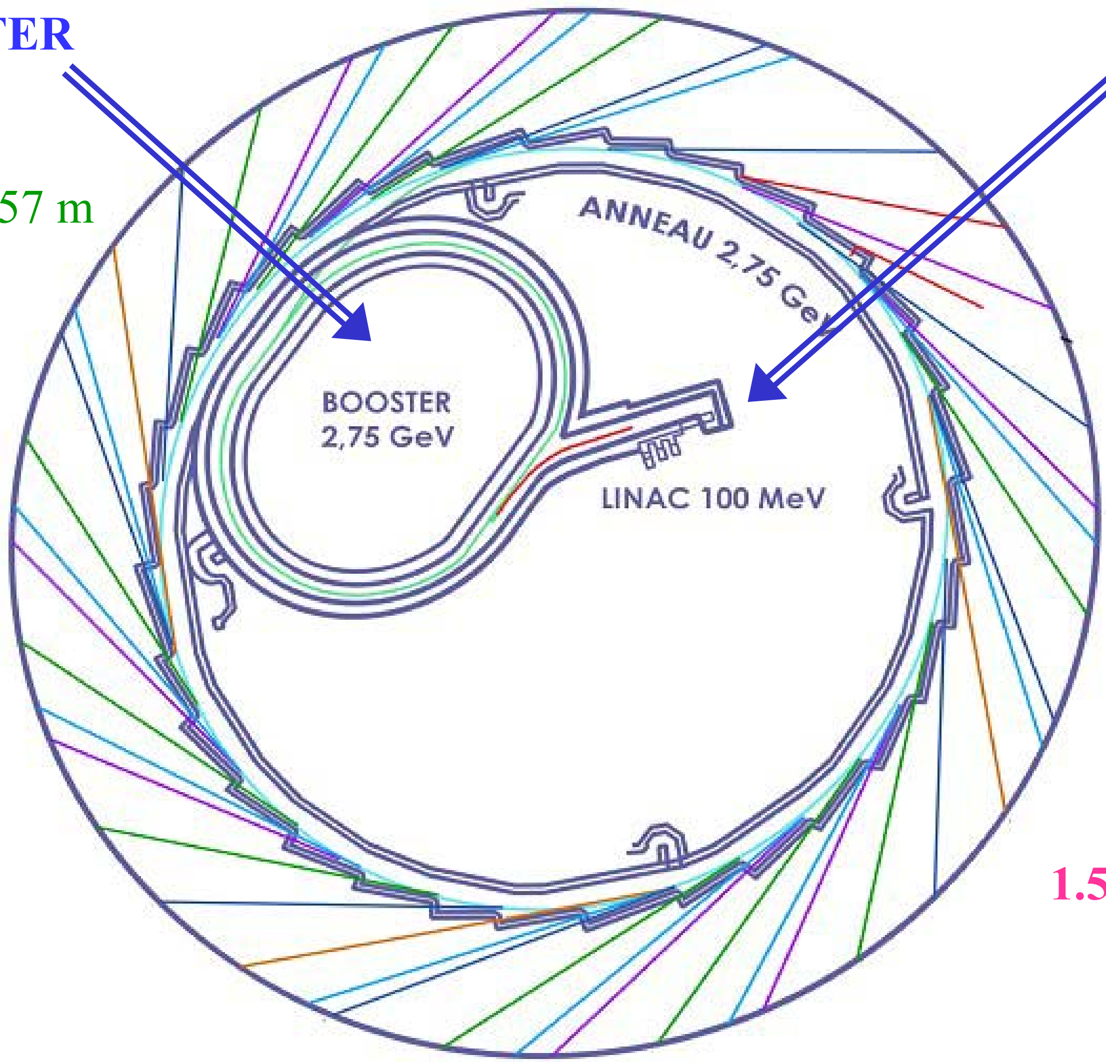
2 super periods
Circumference: 157 m

36 Dipoles :
0.67 T / 2.17 m

44 Qpoles:
10.3 T/m - 0.4 m

Emittance:
110-150 nm.rad

Power supplies cycling at 3 Hz



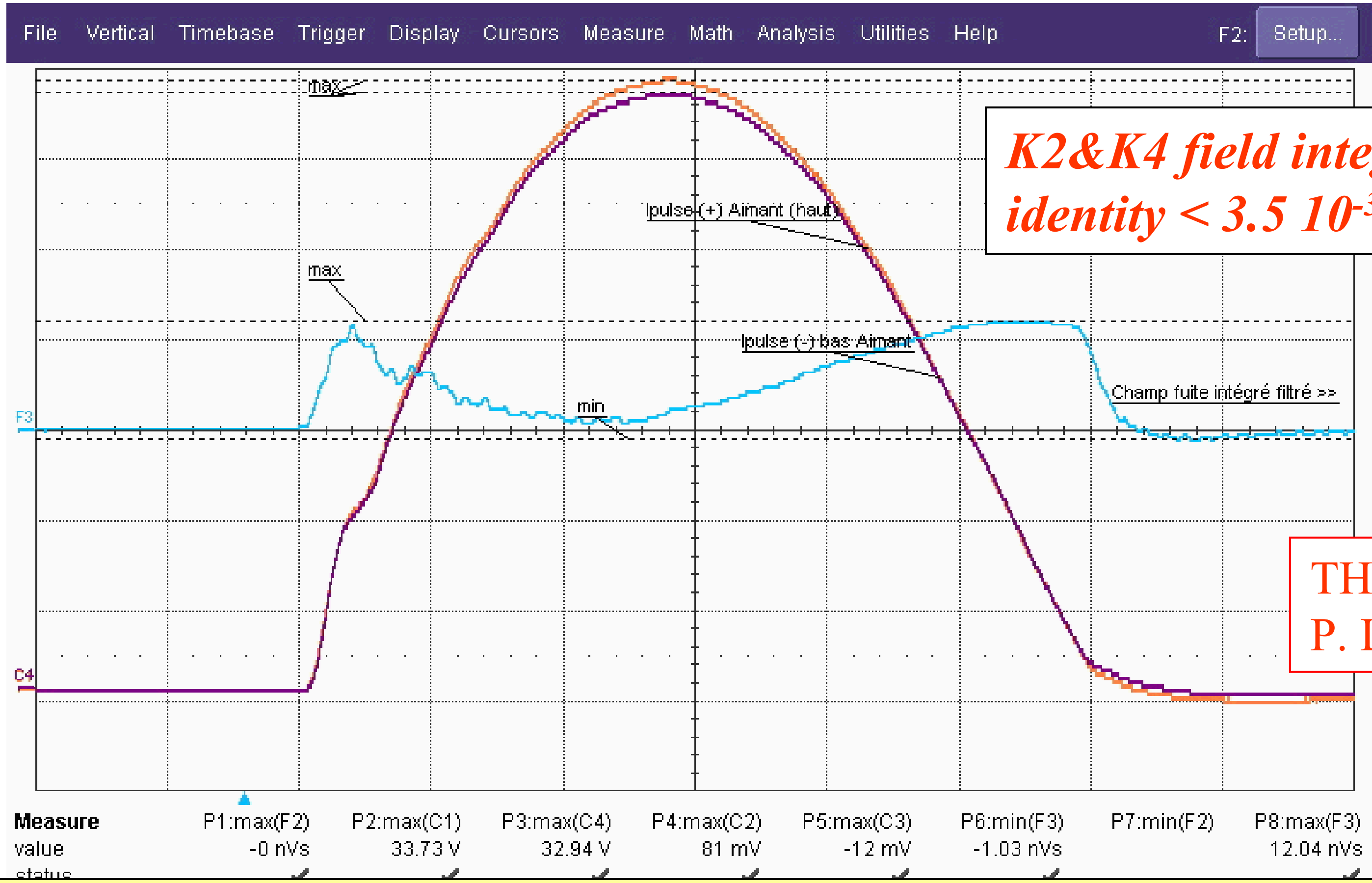
LINAC
100 MeV
3 Hz rep Rate

Output charge :
8 nC in 300 ns
in multibunch mode
(500 mA in SR)

1.5 nC in 3 pulses (2ns)
in 8 bunch mode
(90 mA in SR)

Storage Ring Injection Kickers

Choice of **solid-state switches** for **all the pulsed power supplies**



K2&K4 field integral identity < 3.5 10^{-3}

THPLS100
P. Lebasque

3 HV modules in // based on **fast IGBT** => **matched kickers, able to permit a very steady operation for Top-Up injection**.
The PS's create **8 kV-5.6 kA** pulses, width **6.5 µs half sine**, **low jitter < 0.5 ns**.

Storage Ring Septum magnet

Eddy current septum magnet leakage field strongly reduced

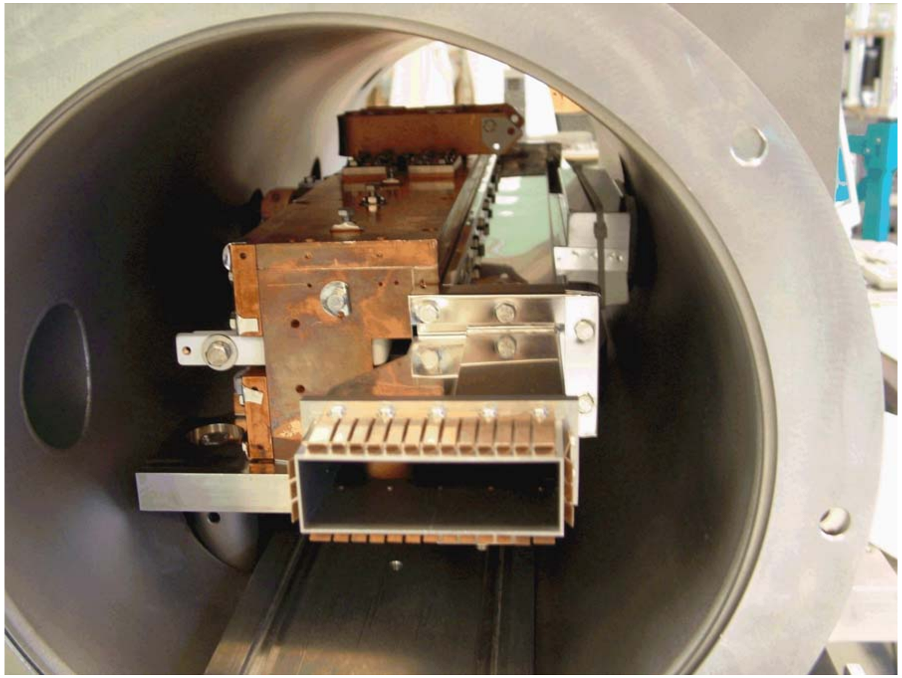
=> Full sine excitation (150 µs)

=> Optimised shielding screen

THPLS101
P. Lebasque

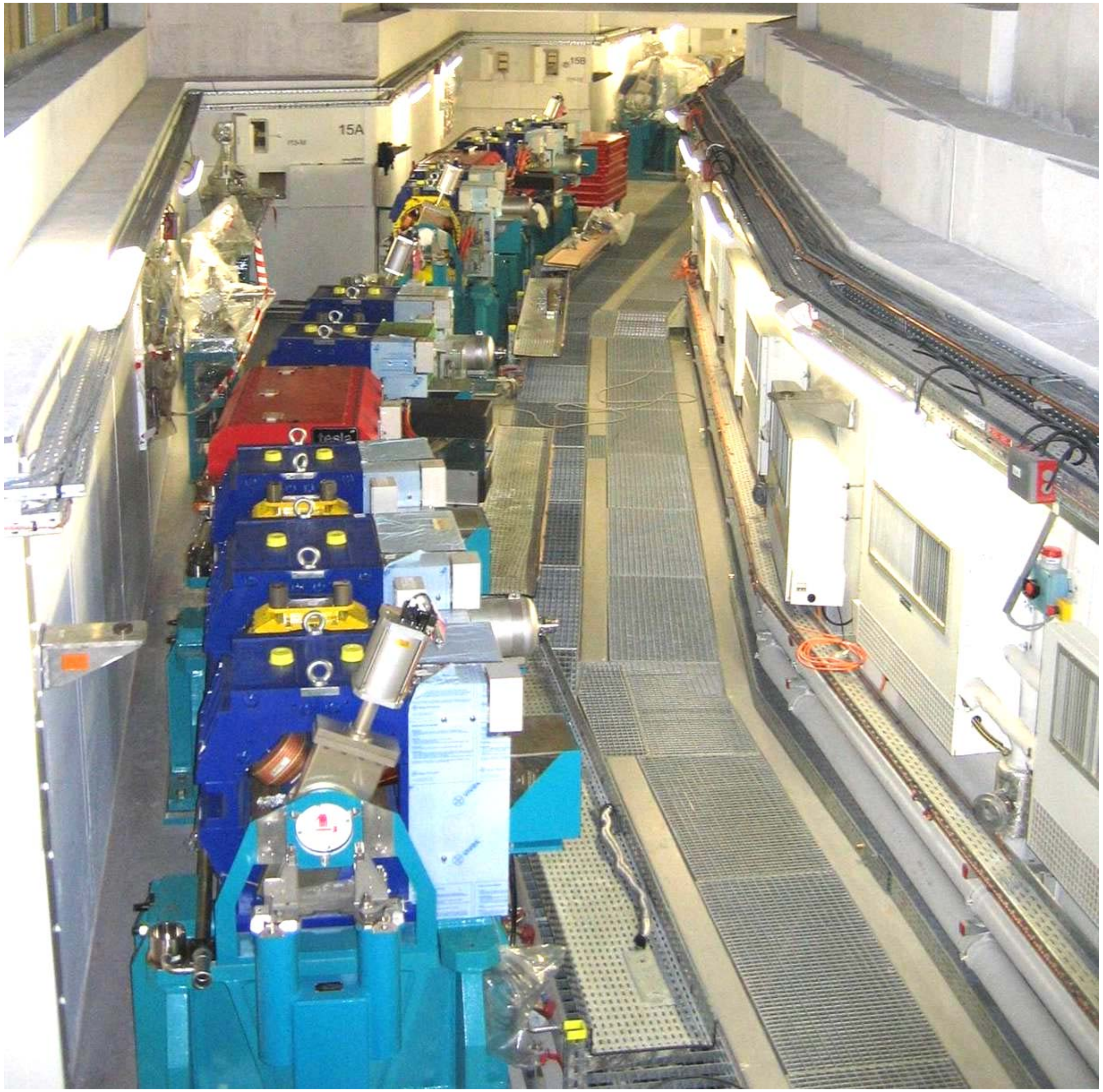
I_{leak}< 4µT.m => 10 ppm of main field integral (255 mT.m)

SuperImphy shielding screen around the stored beam chamber



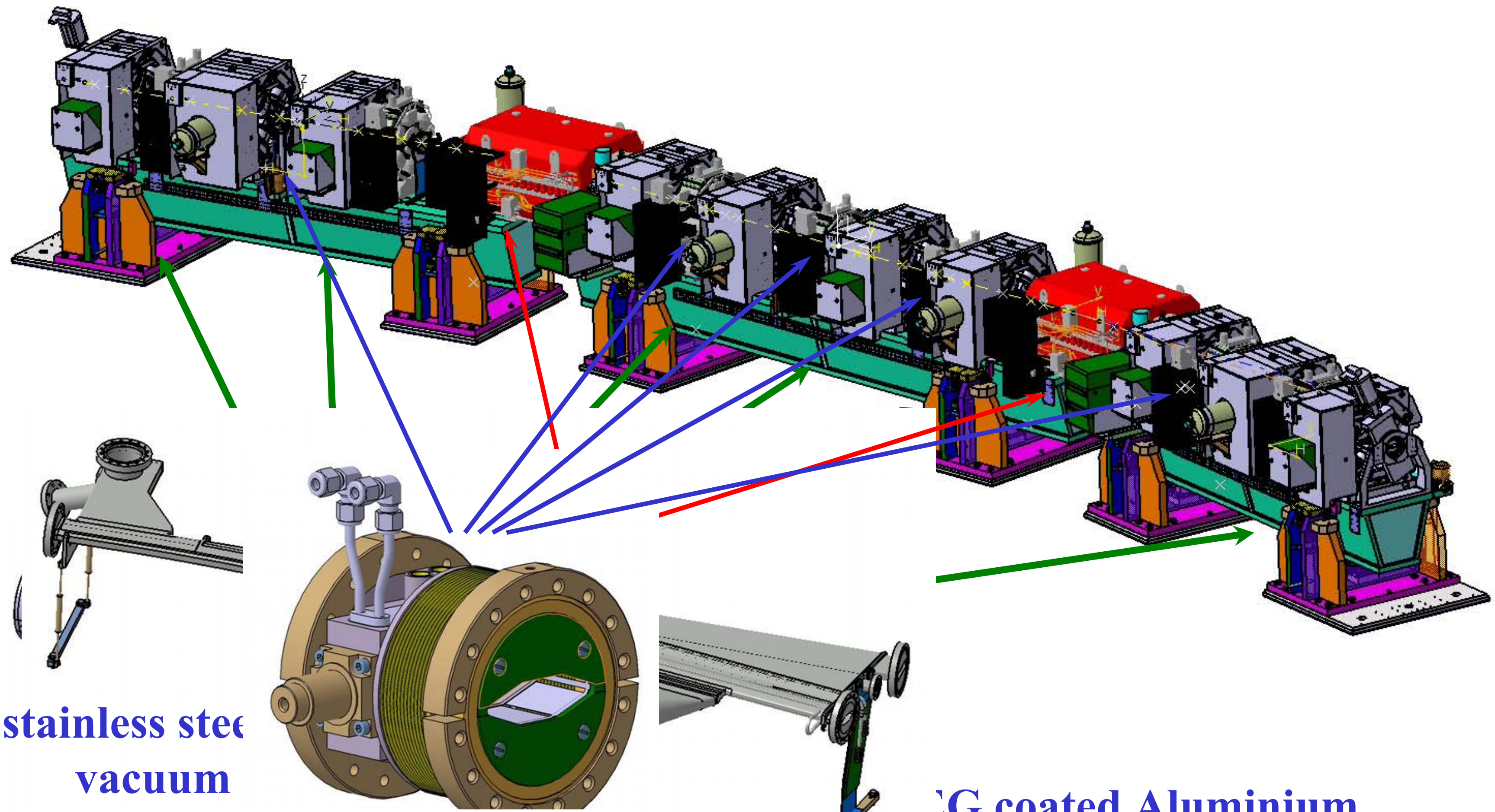
The septum magnet with its shielding screen

Storage Ring



Storage Ring Vacuum system

Vacuum system for one typical cell



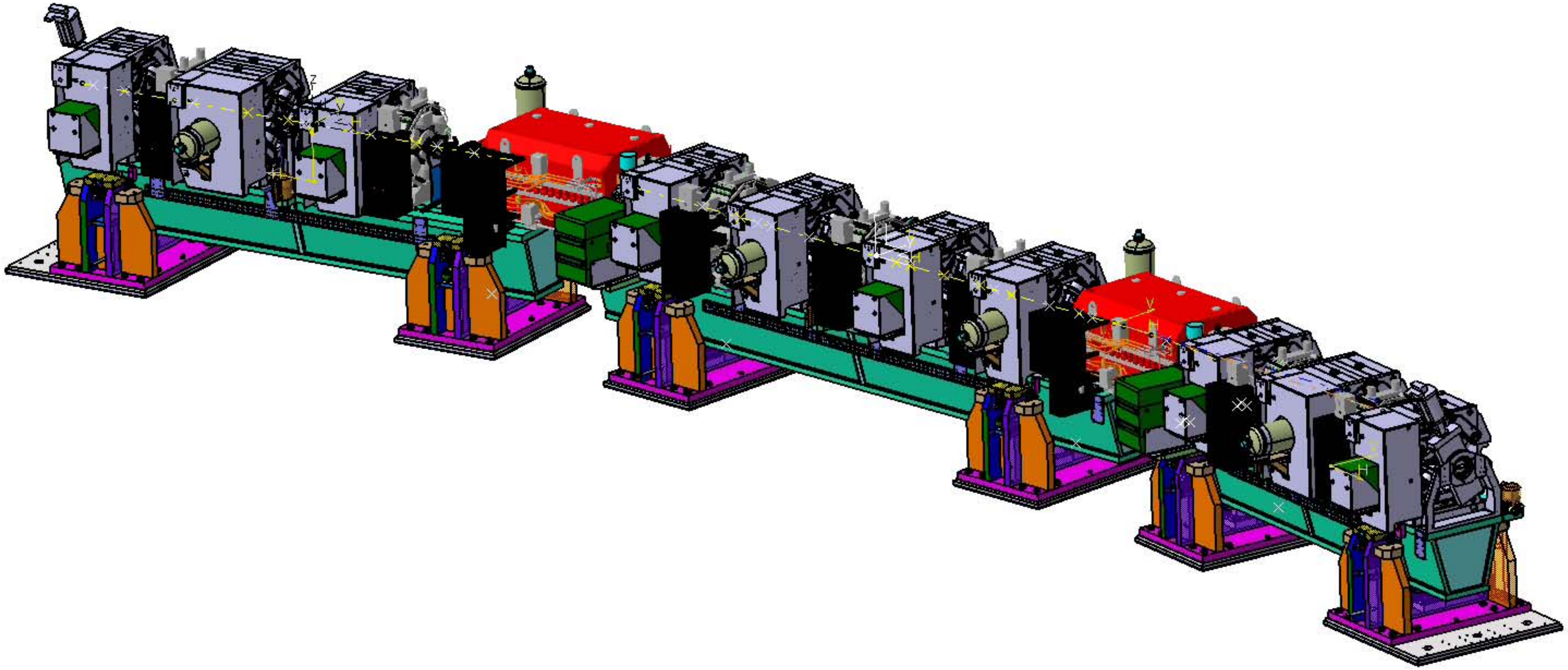
2 stainless stee
vacuum

5 stainless steel BPM-Bellows modules with RF shield (COMVAT/RIAL)

:G coated Aluminium drupole type vacuum vessels with SS/Al flanges (SDMS/SAES)

Storage Ring Vacuum system

Vacuum system for one typical cell



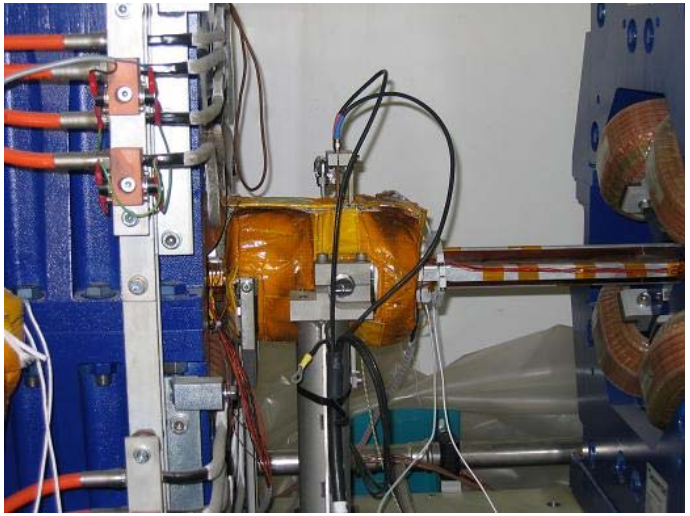
Together with the Straight Sections chambers,
~200 m of NEG coated Al chamber (56% of the ring)

SOLEIL = first SR Machine with extensive use of NEG coated AL vessels

In-situ Bake-out of vacuum vessels

Goals :

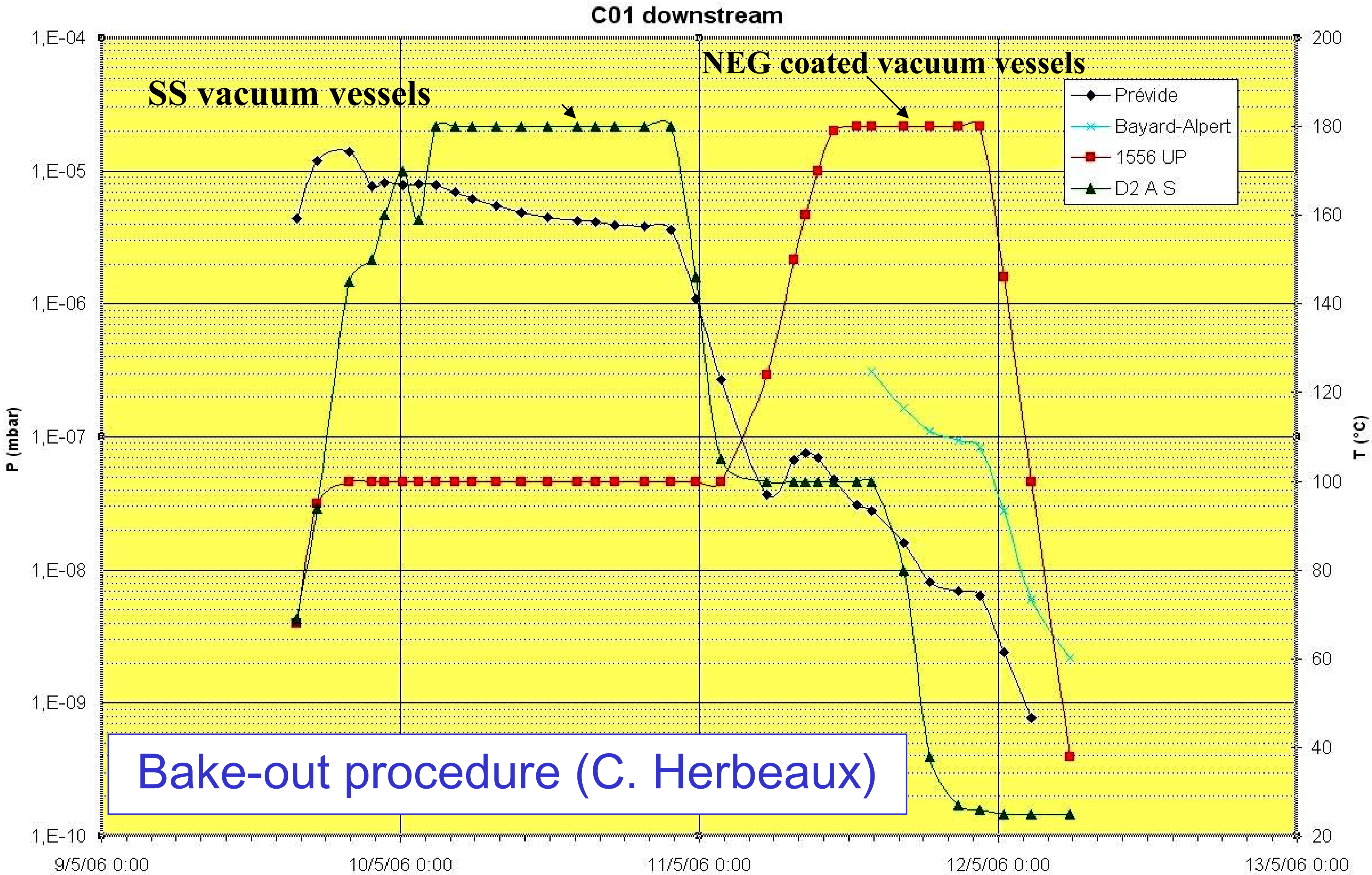
- Outgassing all vacuum parts
- Activation of NEG coating deposited on the quadrupole chambers



Method :

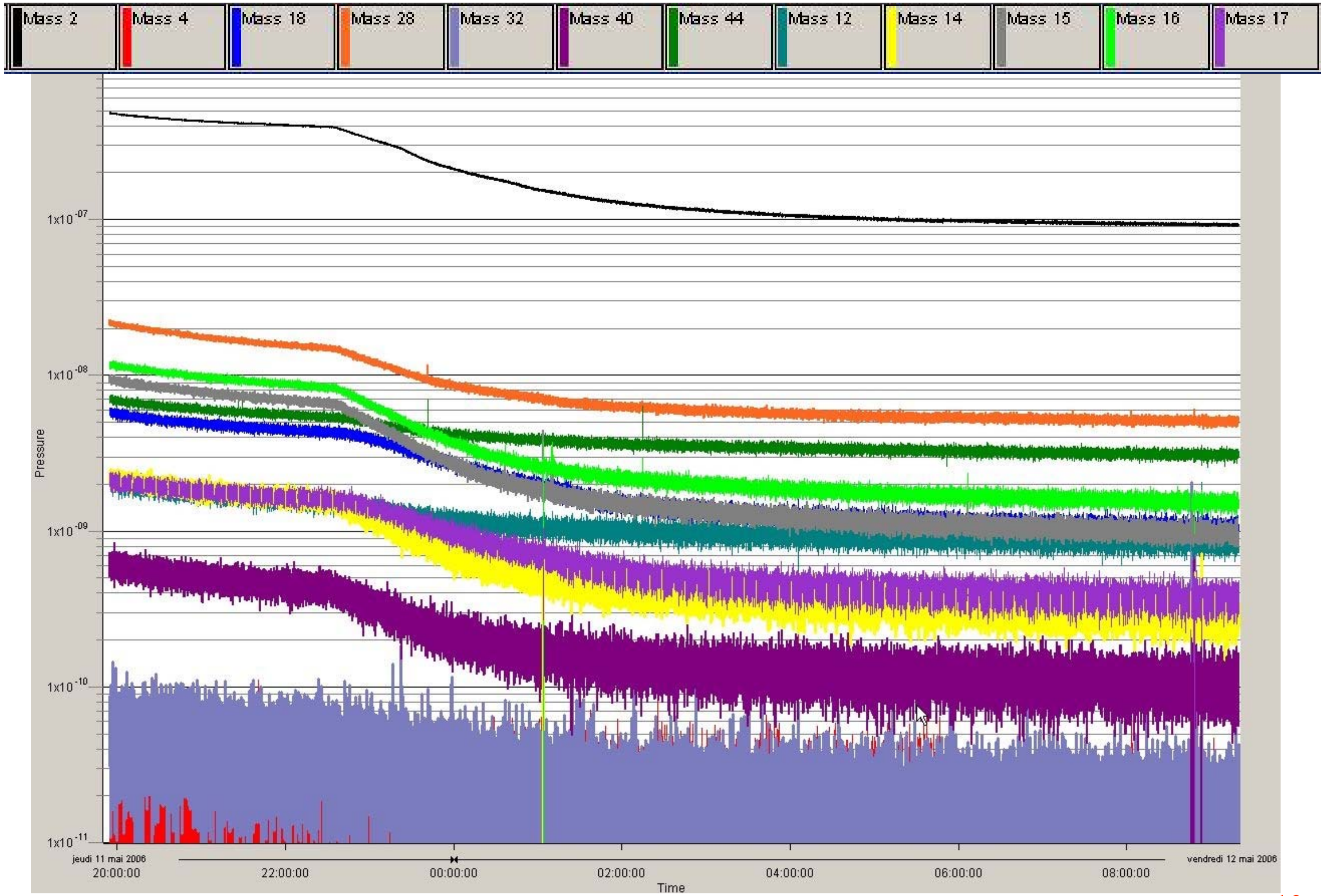
- Heating of the vacuum chambers up to 180°C
- Use of resistive heaters deposited on 1mm thick Kapton foil, glued onto the vessels

Storage Ring Vacuum system



Storage Ring Vacuum system

Partial pressures at the end of the bake-out



After bake-out, the total pressure measured in a cell is in the low 10^{-10} mbar range. Max pressure ~ 4 10^{-10} mbar is measured close to the crotch absorber

Storage Ring : Vacuum system

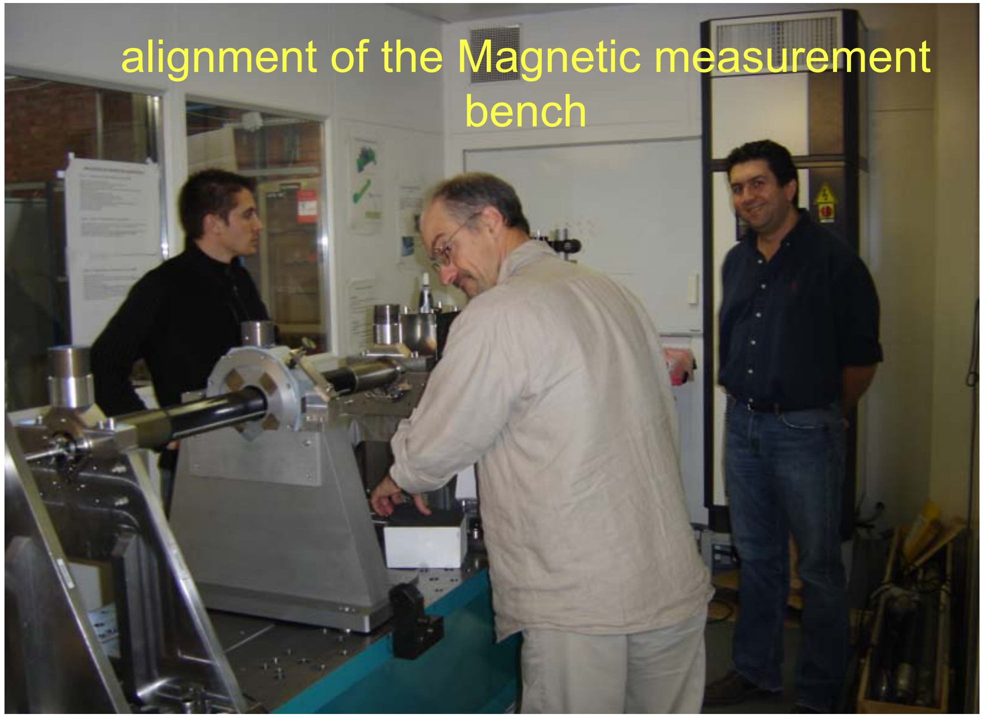
10 small aperture Insertion device chambers (L=5.5 m / h=10 mm) installed before injecting the first electrons ! (First facility to dare doing it !)

Storage Ring : magnets

Dipoles	(38)	: TESLA
Quadrupoles	(160)	: DANFYSIK
Sextupoles	(120)	: SIGMAPHI

Storage Ring : magnetic measurements

Very careful metrology to reach excellent alignment



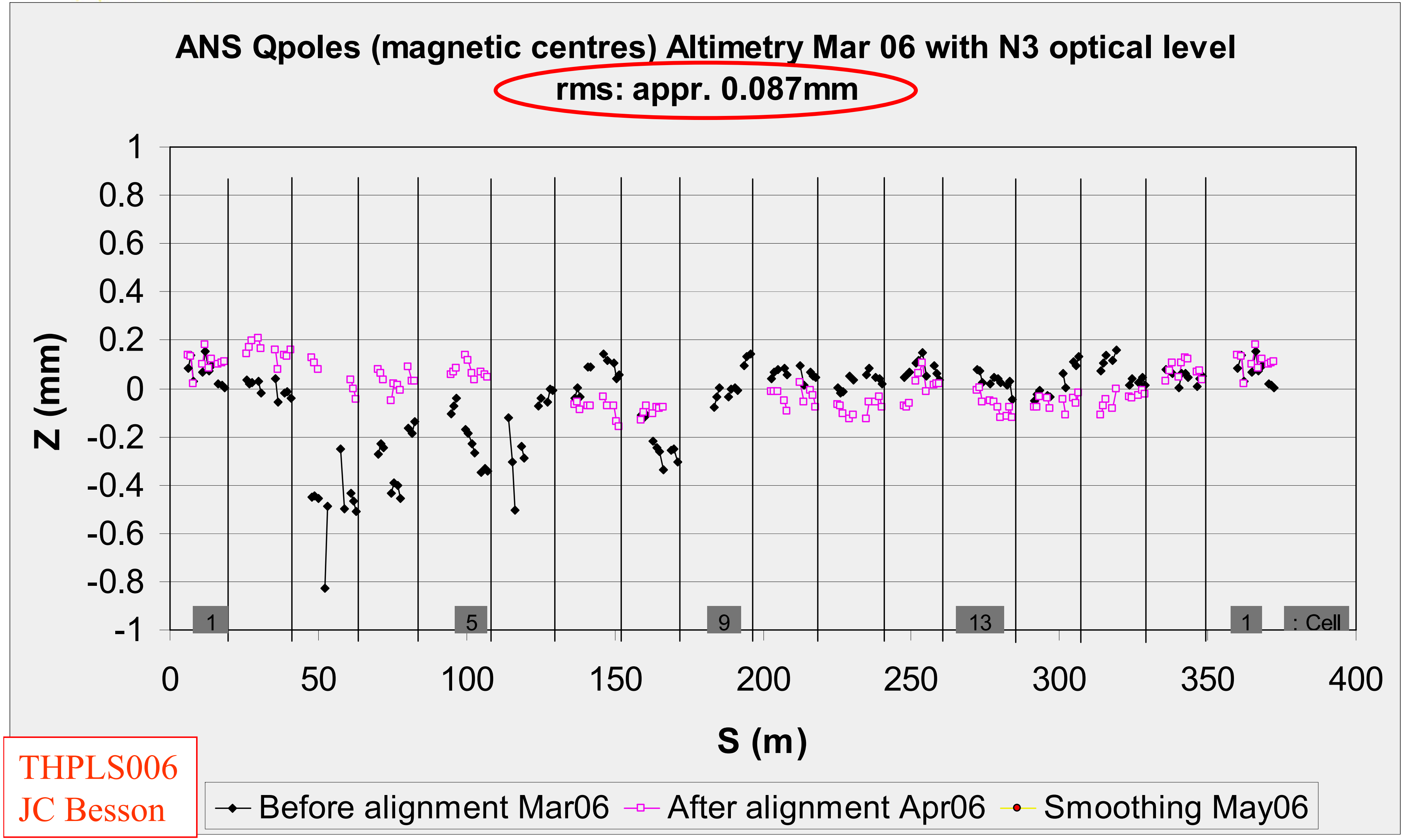
May 2004-Aug. 2005
Magnetic measurements of 326 electro-magnets : magnetic axis centering, field properties

rotating coil bench built to reach magnetic centering to
± 25 µm and tilt ±0.1mrad

THPLS007
P. Brunelle

Table 1	Statistical analysis of measurements			
	Quadrupoles		Sextupoles	
	Mean Value	RMS value	Mean Value	RMS value
ΔX (microns)	1.5	8.4	-3	15
ΔZ (microns)	2.6	7.5	2	10
Tilt (mrad)	0.008	0.040	0.010	0.100

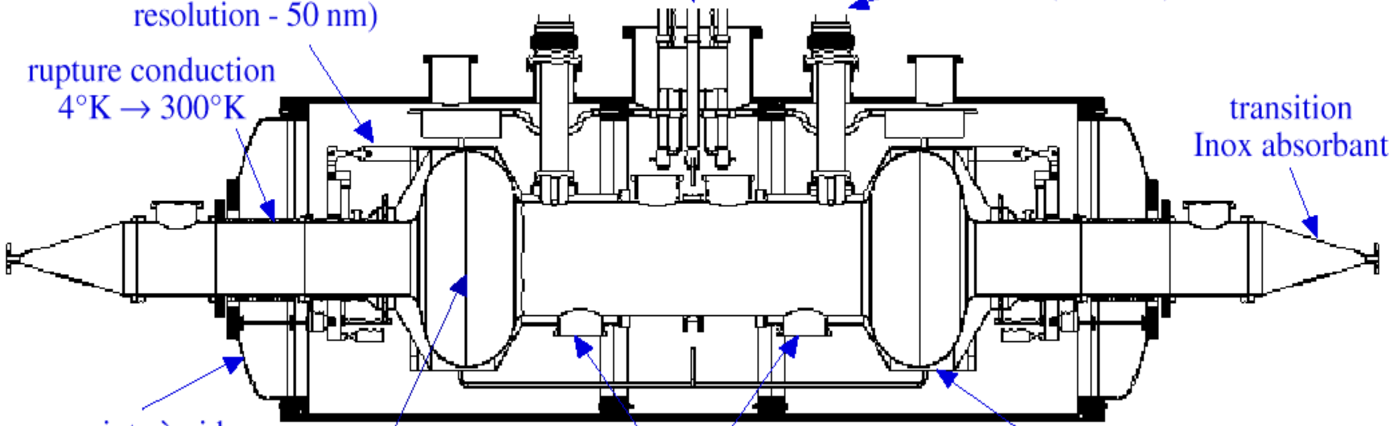
Storage Ring : Magnet alignment



THPLS006
JC Besson

Storage Ring RF system

Design and construction of a dedicated cryomodule with 2 SC cavities so as to provide HOM free operation up to 500 mA. (Collab CEA/CERN/SOLEIL/ESRF)



- → **Prototype tested initially at CERN and ESRF (2000-2002)**
- → **Completely refurbished**
- → **Tested at CERN (Oct 05).**
- → **Installed On the Ring (Nov 05).**
- → **Cooled @ 4 K since May 10, 2006**
- → **RF conditioned since May 24, 2006 (150 kW/coupler)**

MOPCH142
P. Marchand

1st cryomodule inside SR tunnel

1st cryomodule will enable alone operation up to 300 mA.
A 2nd cryomodule is being built by ACCEL for operation at 500 mA (2nd half of 2007)

Solid state RF Amplifiers

Motivation : No klystrons suitable to the power required at SOLEIL

- **Solid state amplifier : → 1st unit (40 kW) built for the Booster (2004)**

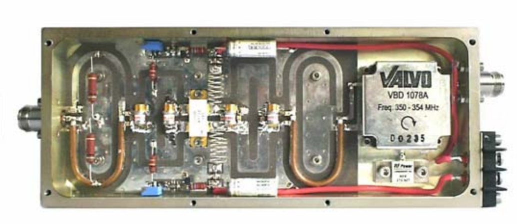
MOPCH142
P. Marchand

→ Decision to use this technology for the Storage Ring

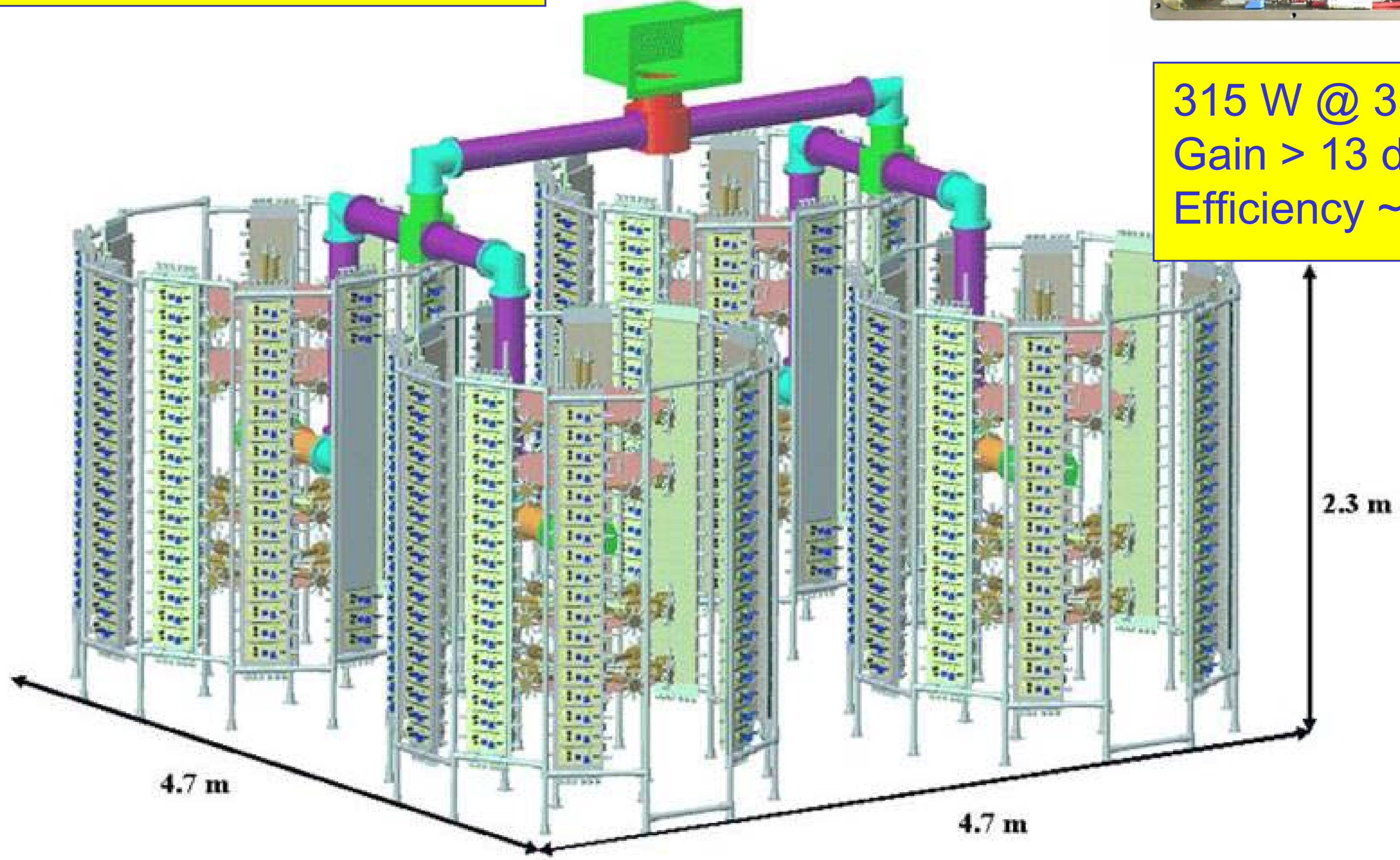
Storage Ring RF amplifier

4 x 190 kW power amplifiers

4 x 47kW solid state amplifiers
724 modules



315 W @ 352 MHz
Gain > 13 dB
Efficiency ~60%



Storage Ring RF plant

4 x 190 kW power amplifiers

190 kW @ 352 MHz
Gain = 52 dB
Overall Efficiency (PS,..) ~50%

<u>Full Cost (with PS and WG distribution)</u>
Booster : 200 k€ for 40 kW => 5 € / W
Stor. Ring : 3 M€ for 750 kW => 4 € / W
Modularity = You just pay for the W you actually need

Storage Ring RF amplifiers

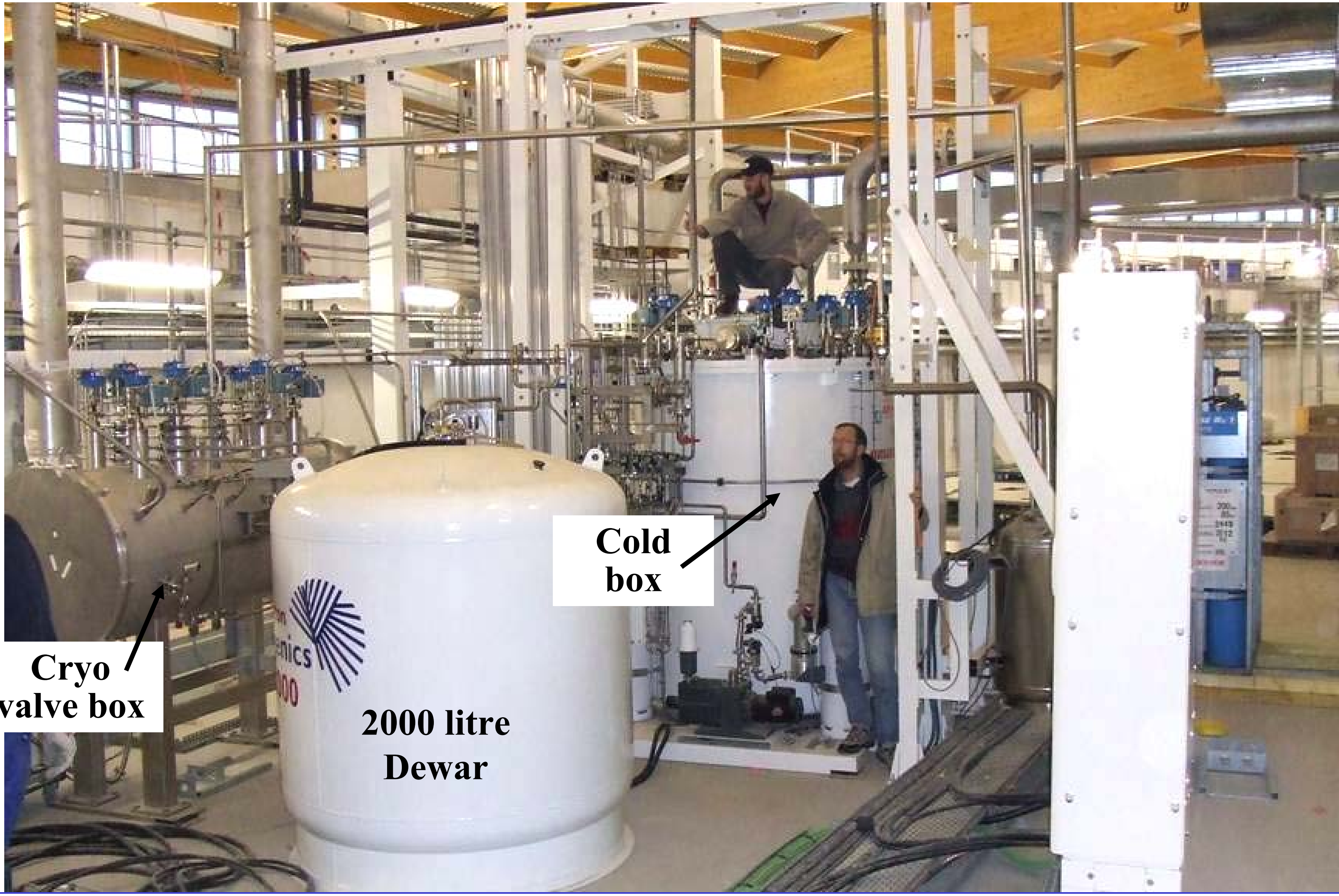
April 6th, 2006 : 180 kW from amplifier n°1

World record !

Highest RF power produced with transistors

April 7th , 2006: 180 kW from amplifier n°2

Cryogenic source (Air Liquide) in RF area
400 W @ 4K + 50 l/h liquid He production



Storage Ring : Diagnostics

120 BPMs (LIBERA modules from I-Tec) featuring :

- sub micron resolution
- turn by turn capability (worked nicely during commissioning)

TUPCH008
JC Denard

2 DCCTs, 1 FCT (Bergoz)

1 visible light monitor, 1 pinhole camera, 1 streak camera

Tune monitors and striplines

H and V scrapers

Fast and slow beamloss monitors

TANGO control system

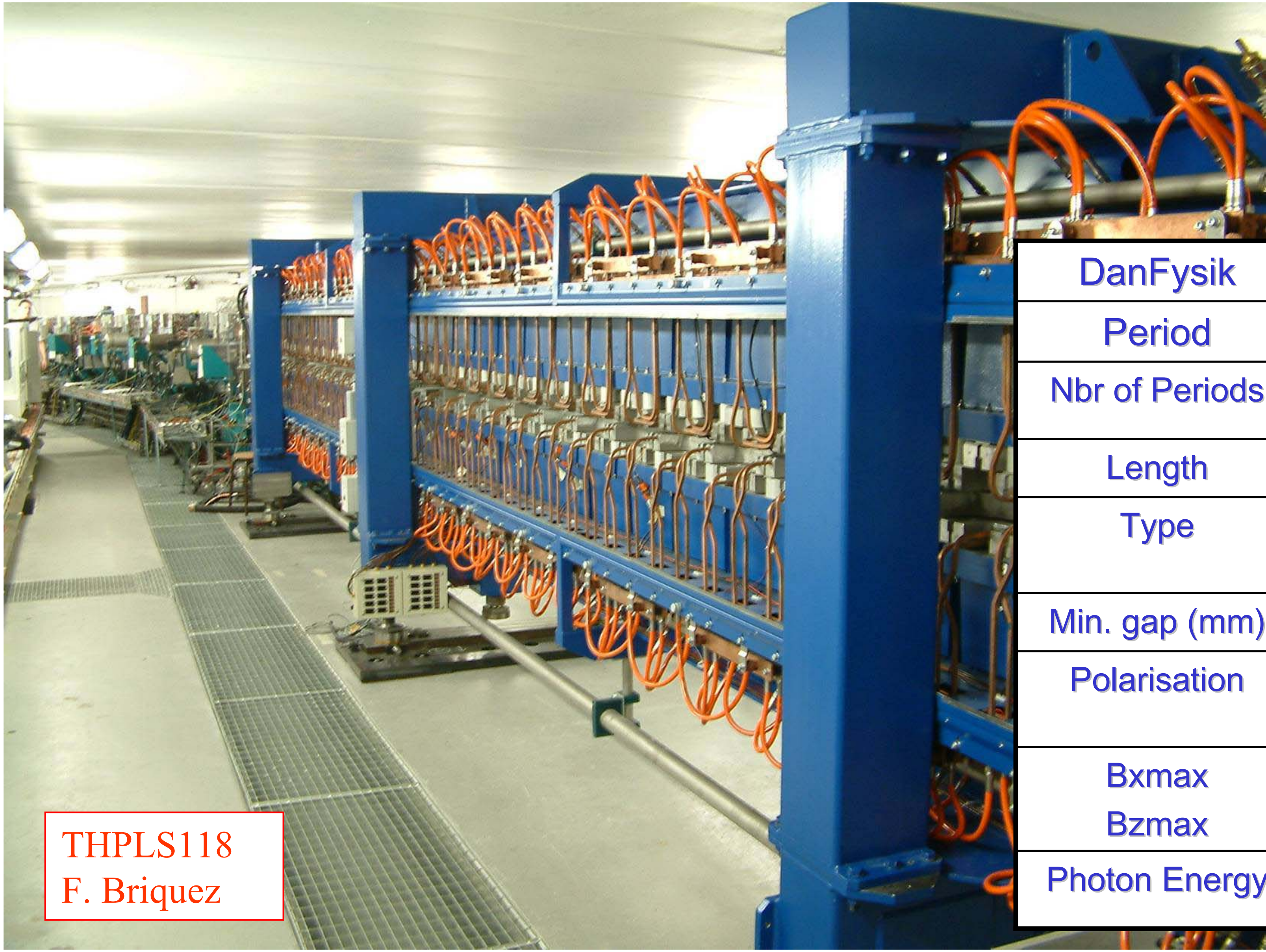
SOLEIL first facility using TANGO at full scale

Collaboration ESRF/ELETTRA/SOLEIL/ALBA

- easy and efficient tools to control any equipment
- data archiving
- control of all equipments from the control room
- supervision done using “Global Screen” applications (developed by operators)
- All hardware installed (Crate with CPCI and boards, PLC’s..)
- Machine commissioning : Matlab applications (Matlab Middle Layer Toolkit...)

THPCH109
A. Nadolski

Electromagnet Helical Undulator HU640



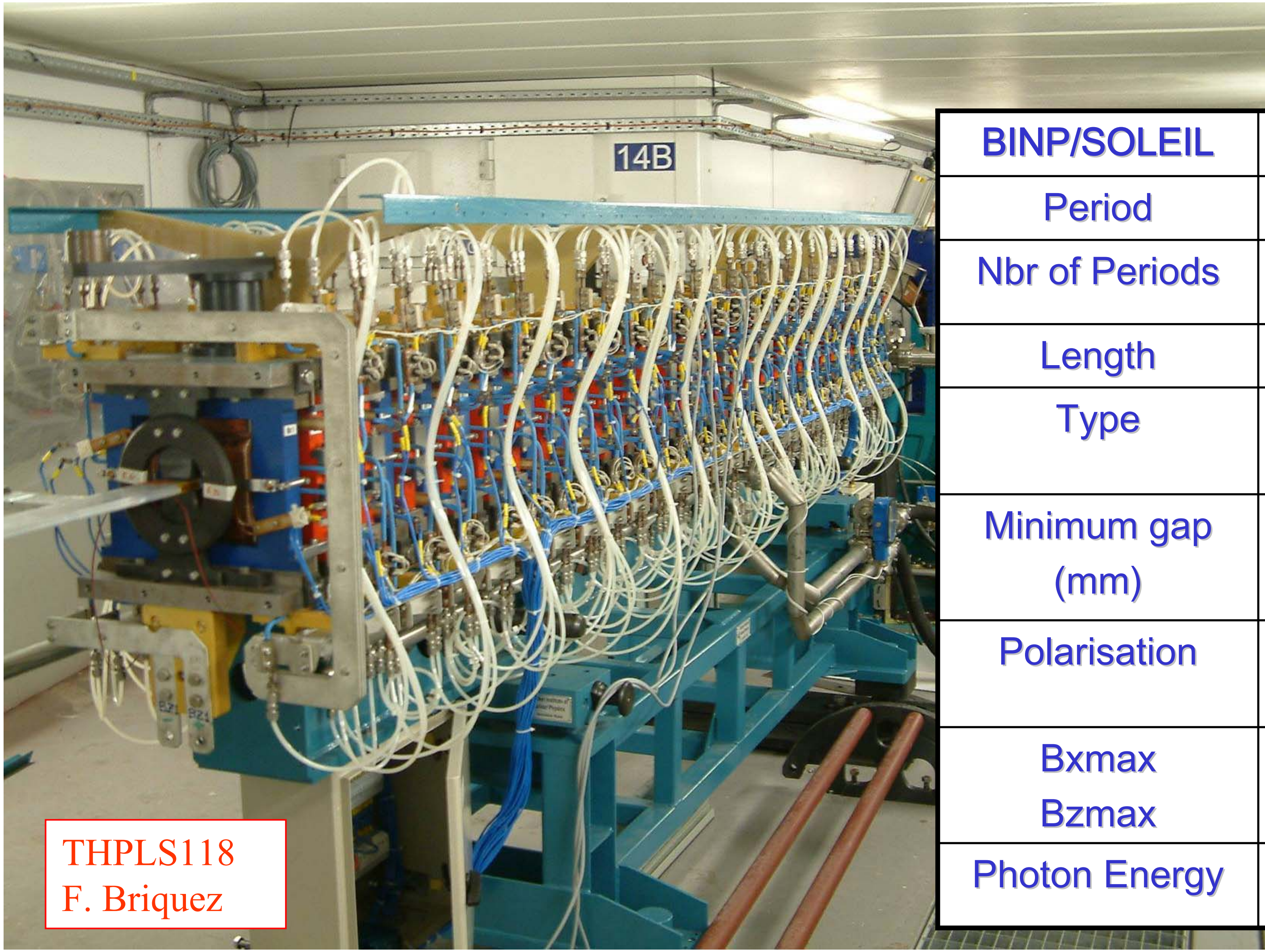
DanFysik	HU640
Period	640 mm
Nbr of Periods	14
Length	10.0 m
Type	Electro-magnetic
Min. gap (mm)	19
Polarisation	Circ./Lin. adjustable
Bxmax Bzmax	0.09 T 0.11 T
Photon Energy	5 – 40 eV

THPLS118
F. Briquez

Vacuum chamber for HU640

- Al extruded up to 10 m long
- Water cooled
- NEG coated in 2 parts 5m long (SAES)
- Welded together (CINEL)

Electromagnet Helical Undulator HU256



BINP/SOLEIL	3 x HU256
Period	256 mm
Nbr of Periods	12
Length	3.6 m
Type	Electro-magnetic
Minimum gap (mm)	15 (V) 50 (H)
Polarisation	Circ./Lin. H et V
Bxmax Bzmax	0.275 T 0.400 T
Photon Energy	10 – 1000 eV

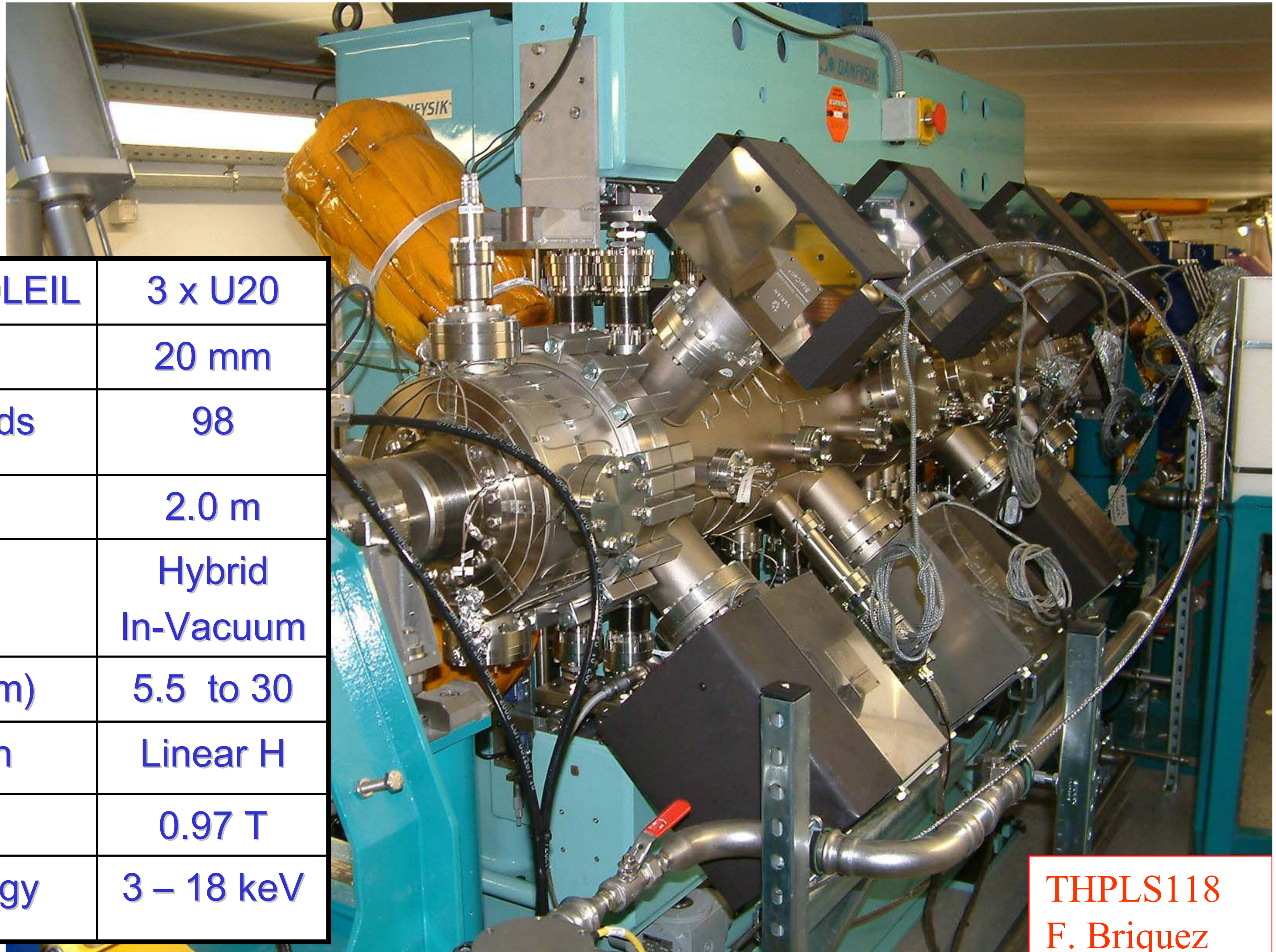
THPLS118
F. Briquez

Apple-II Type Helical Undulator HU80

ELETTRA/SOLEIL	3 x HU80
Period	80 mm
Number of Periods	19
Length	1.65 m
Type	Apple-II
Minimum gap (mm)	15 to 250
Polarisation	Circ./Lin.
Bxmax Bzmax	0.76 T 0.85 [1.0] T
Photon Energy	80 [35] – 1500 eV

THPLS118
F. Briquez

In-Vacuum undulator U20 inside SR tunnel



DANFYSIK/SOLEIL	3 x U20
Period	20 mm
Nbr of Periods	98
Length	2.0 m
Type	Hybrid In-Vacuum
Min. gap (mm)	5.5 to 30
Polarisation	Linear H
Bzmax	0.97 T
Photon Energy	3 – 18 keV

THPLS118
F. Briquez

Commissioning

Linac

Booster

Storage Ring

LINAC

Linac installation completed by THALES in Spring 2005

Integrates 2 Accelerating sections donated by CERN

LINAC

1st beam on July 2nd,2005

Linac heart is beating !

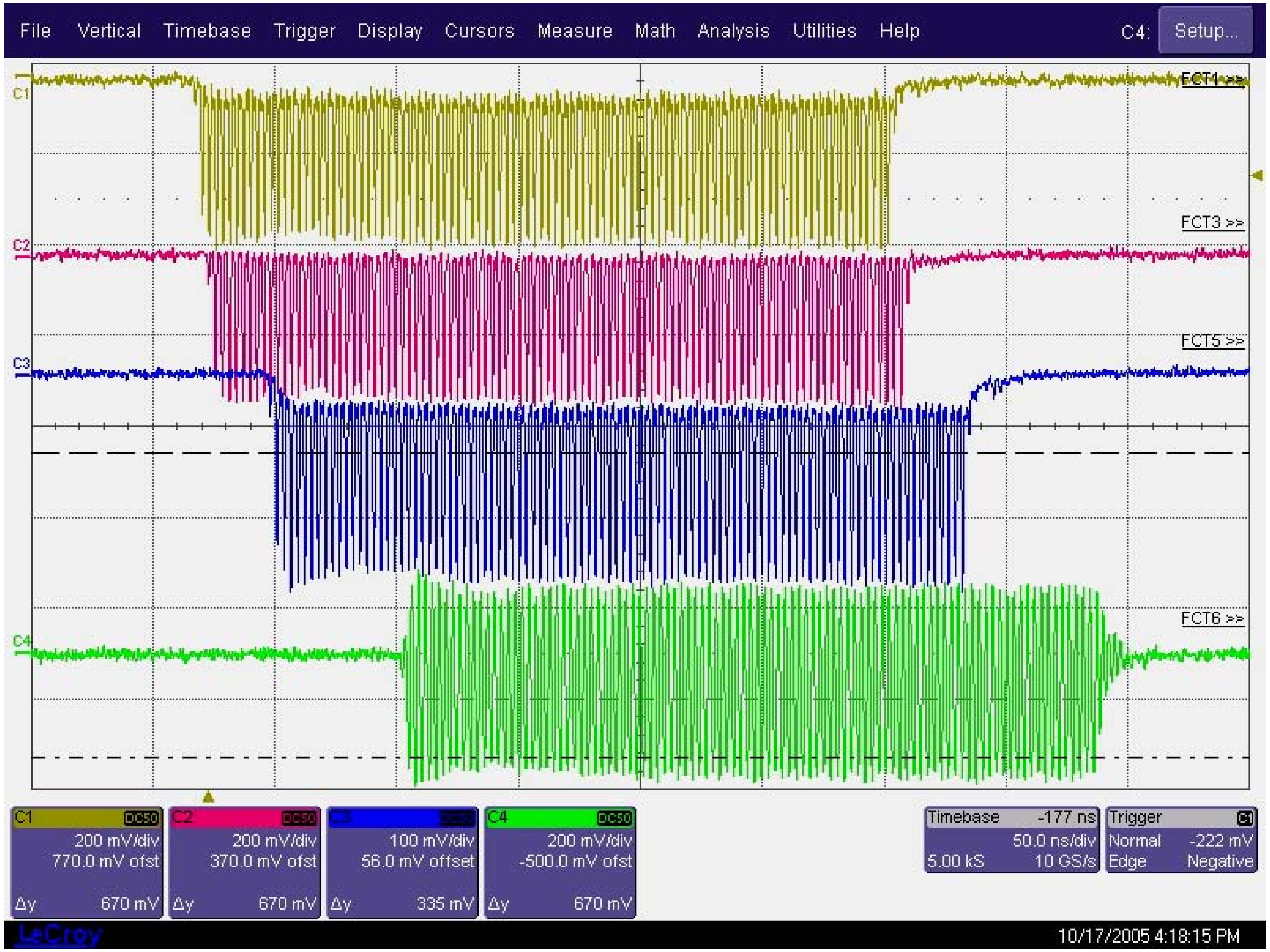
Many experiments and tuning performed by THALES and SOLEIL.

Excellent performances (stability/reproducibility)

Final Acceptance pronounced on November 15th, 2005

LINAC : Long Pulse Mode

Beam transmission



Gun

Buncher input: 85%

Section 1 output: 62%

After Energy analyzing slit: 53%

TUPCH112
A. Setty

LINAC : Short Pulse Mode

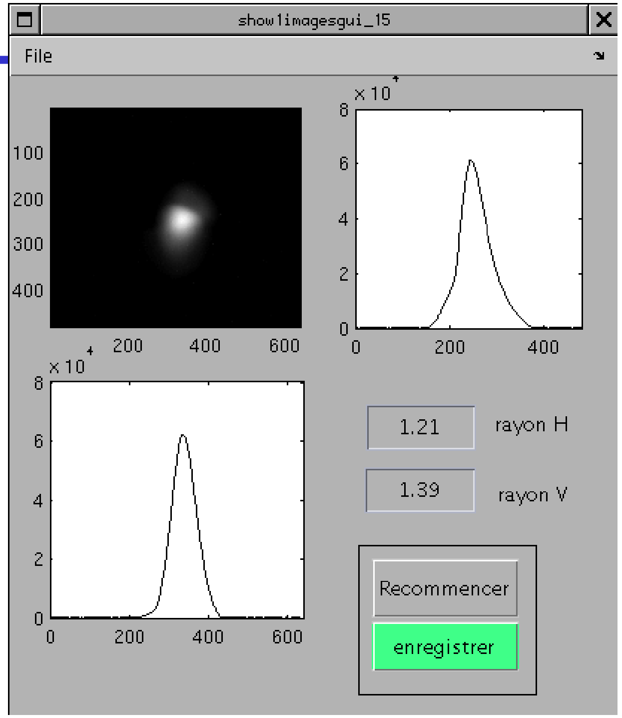
4 pulses with a level's decrease:< 5 %

LINAC

Characterization using TL1 diagnostics :

=> Emittance measurements

=> Energy dispersion



Emittance measurements results

Mode	Beam Charge	Horizontal π mm mrad	Vertical π mm mrad
Long Pulse	10.6 nC	47	52
Short Pulse (1)	0.55 nC	64	67
Short Pulse (4)	2.27 nC	67	78

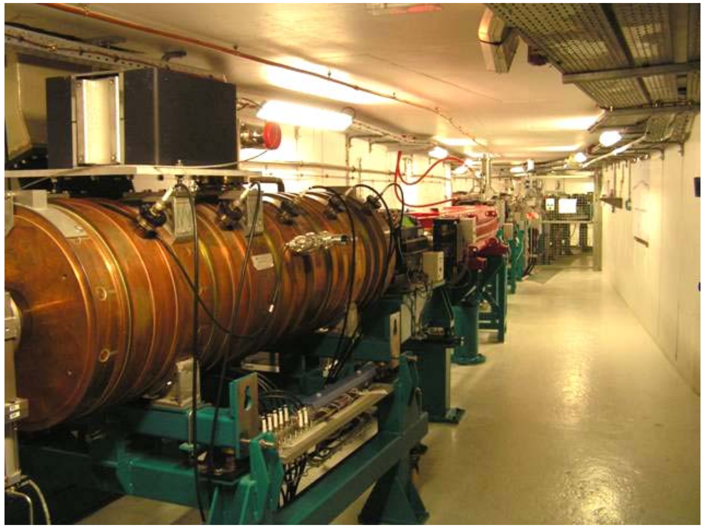
THPLS010
MA Tordeux

(Specifications : (γε at 90 %) < 200 π.mm.mrad)

SOLEIL SYNCHROTRON

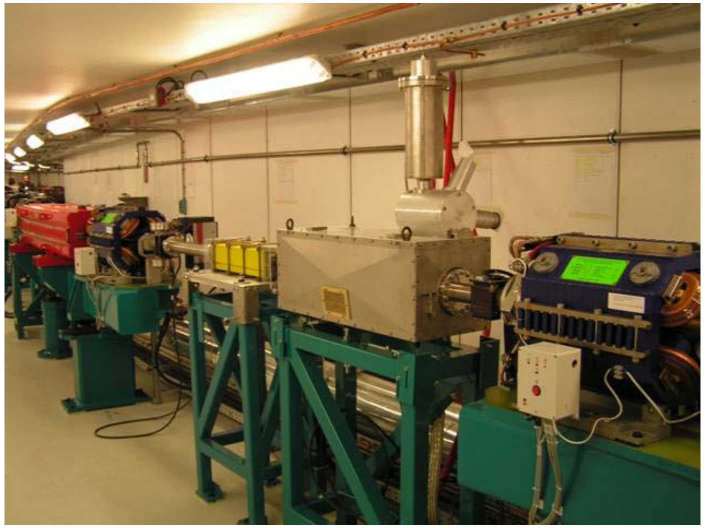
Booster

Arcs



RF Cavity
(LEP)

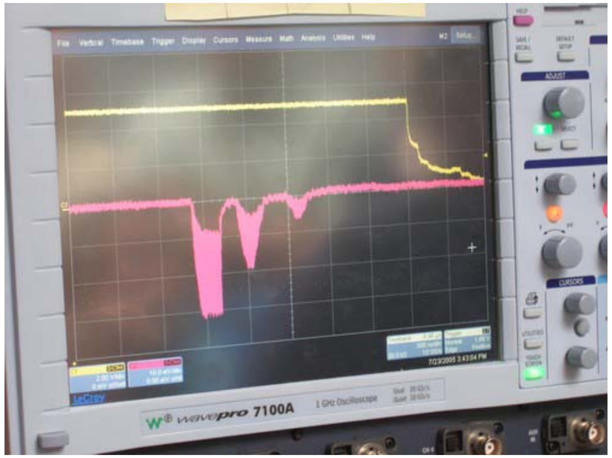
Injection



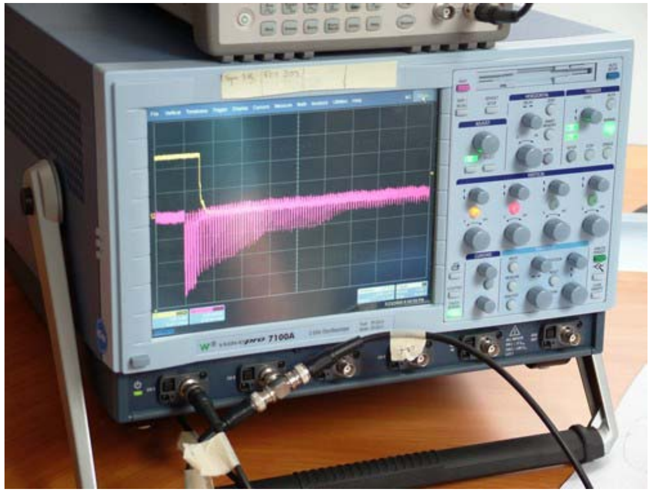
Extraction

Installation was completed in July 2005

1st beam in the Booster at 110 MeV



2 turns !



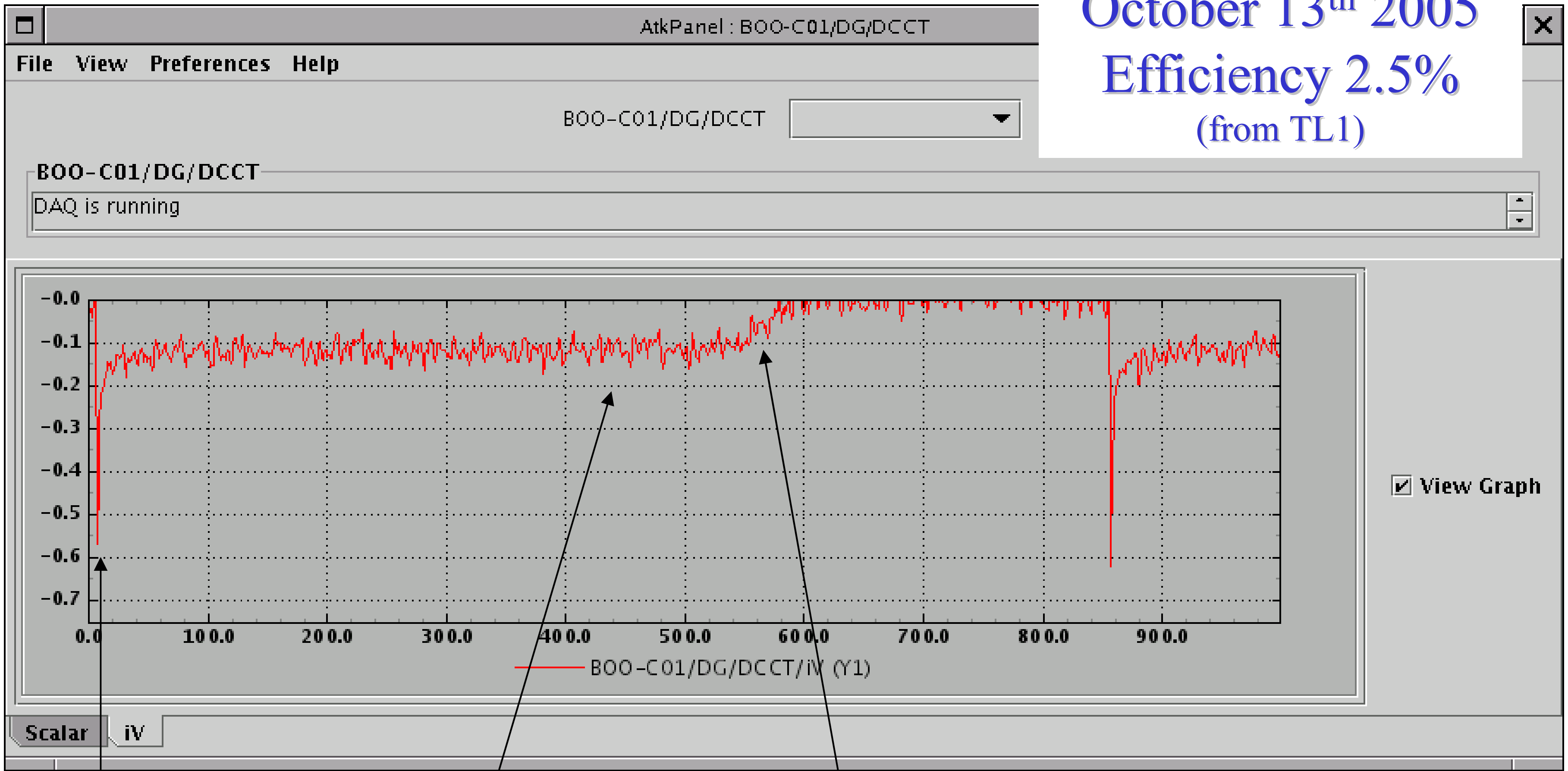
July 23rd 2005

Booster equipment are OK !

Beam stored !

Booster : 1st beam accelerated to 2.75 GeV

October 13th 2005
Efficiency 2.5%
(from TL1)

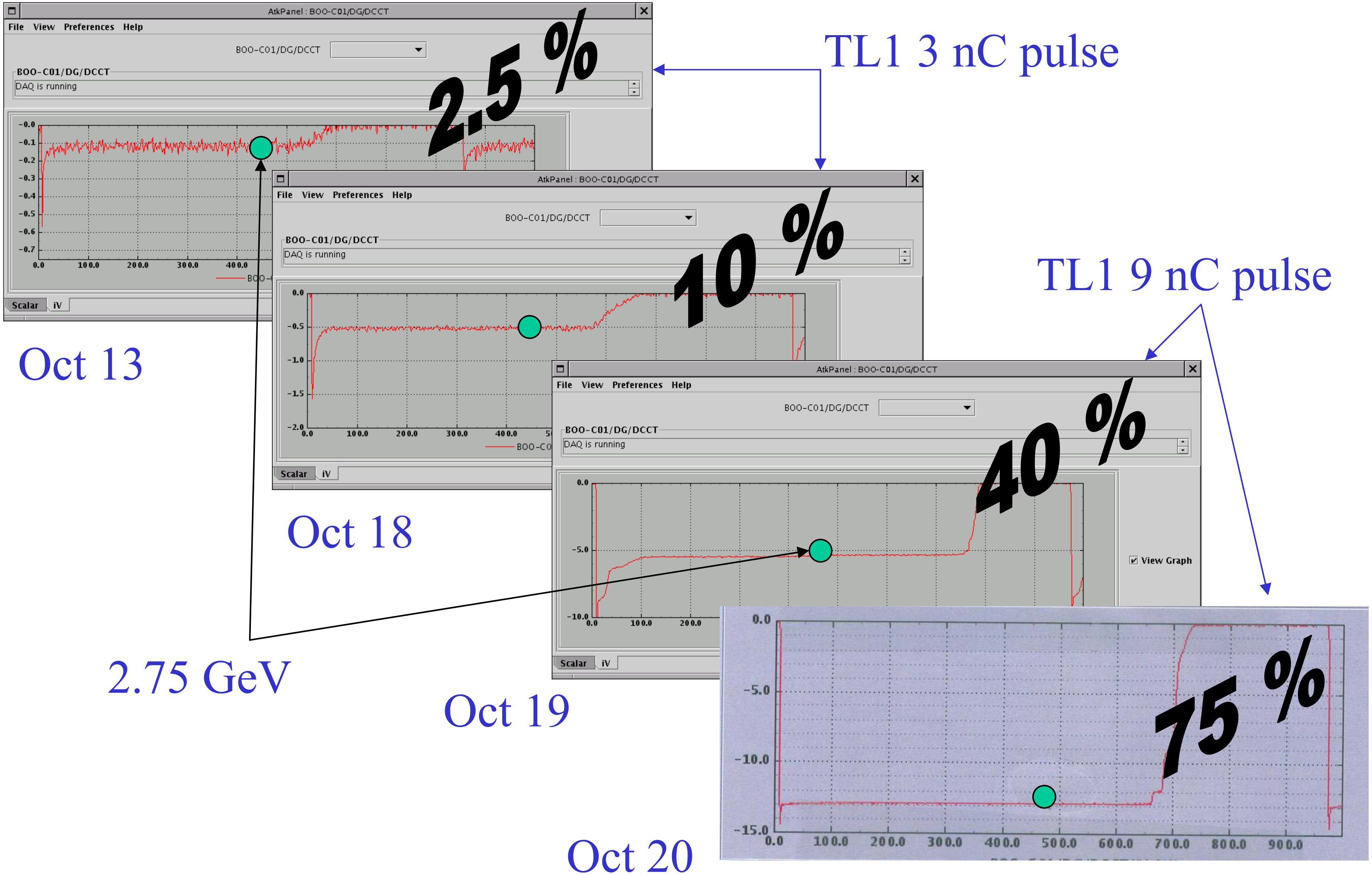


Injection at 110 MeV

2.75 GeV

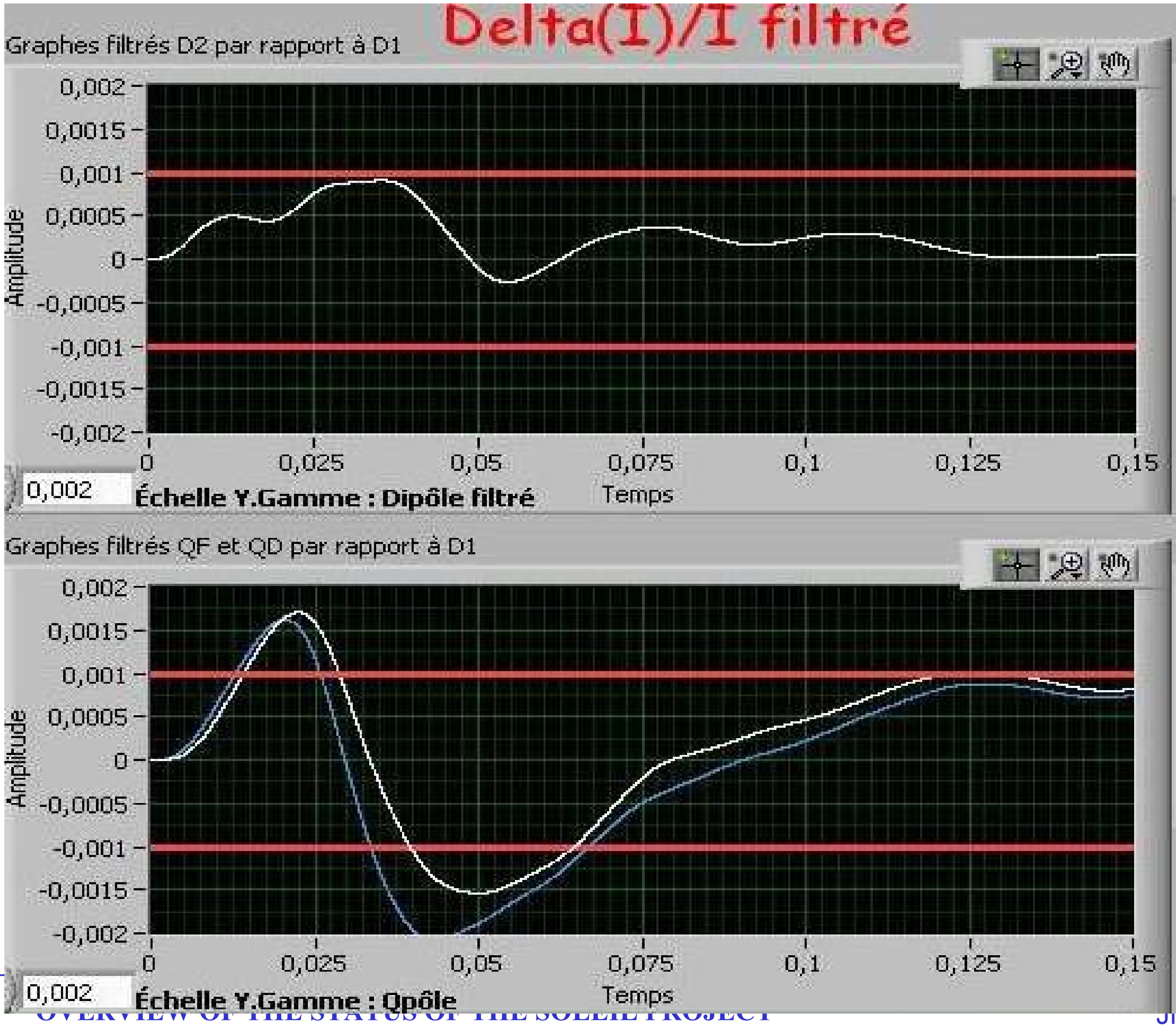
Loss on resonances

Fast increase of the acceleration efficiency



Booster : Power supplies tracking

4 power supplies (Bruker) ramped at 3 Hz : "Tracking" ± 0.2 %



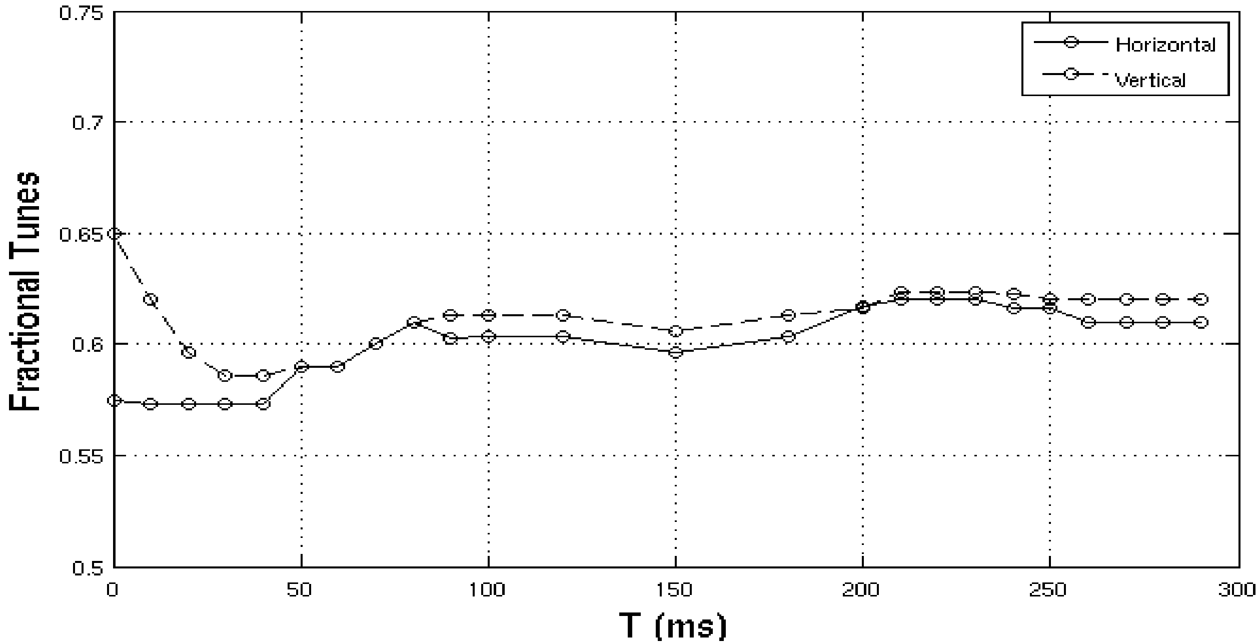
Dipole 1versus
Dipole 2

(2 x 560 A / 1000 V)

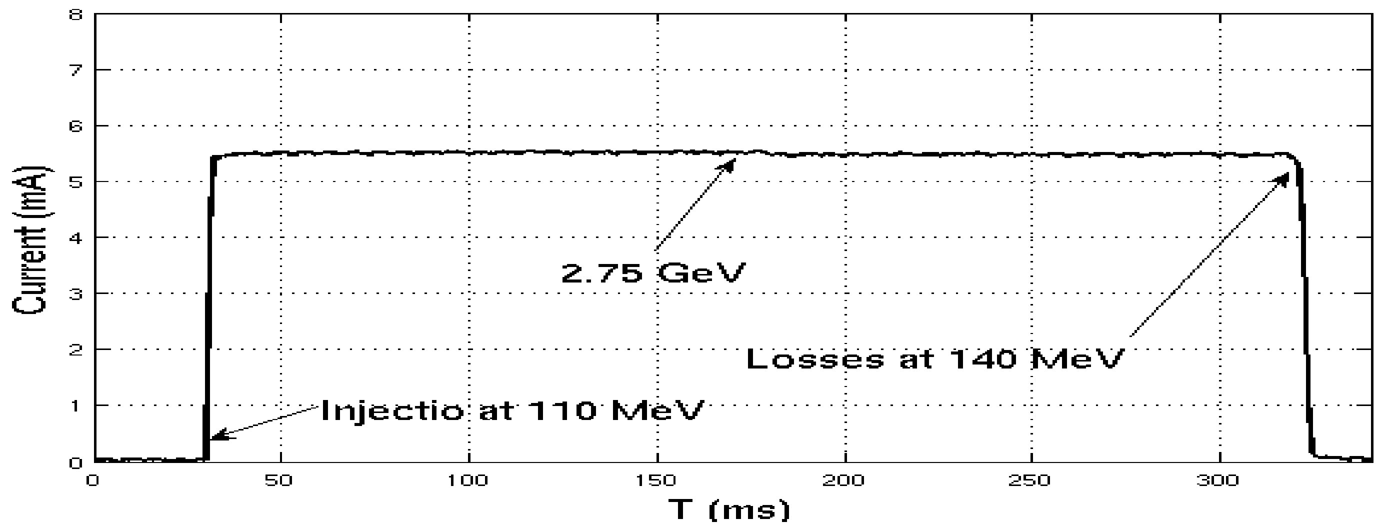
QF, QD
versus
Dipole 1

WEPLS118
P. Gros

Booster Efficiency ~ 90-95 %



Tunes kept within ± 0.05

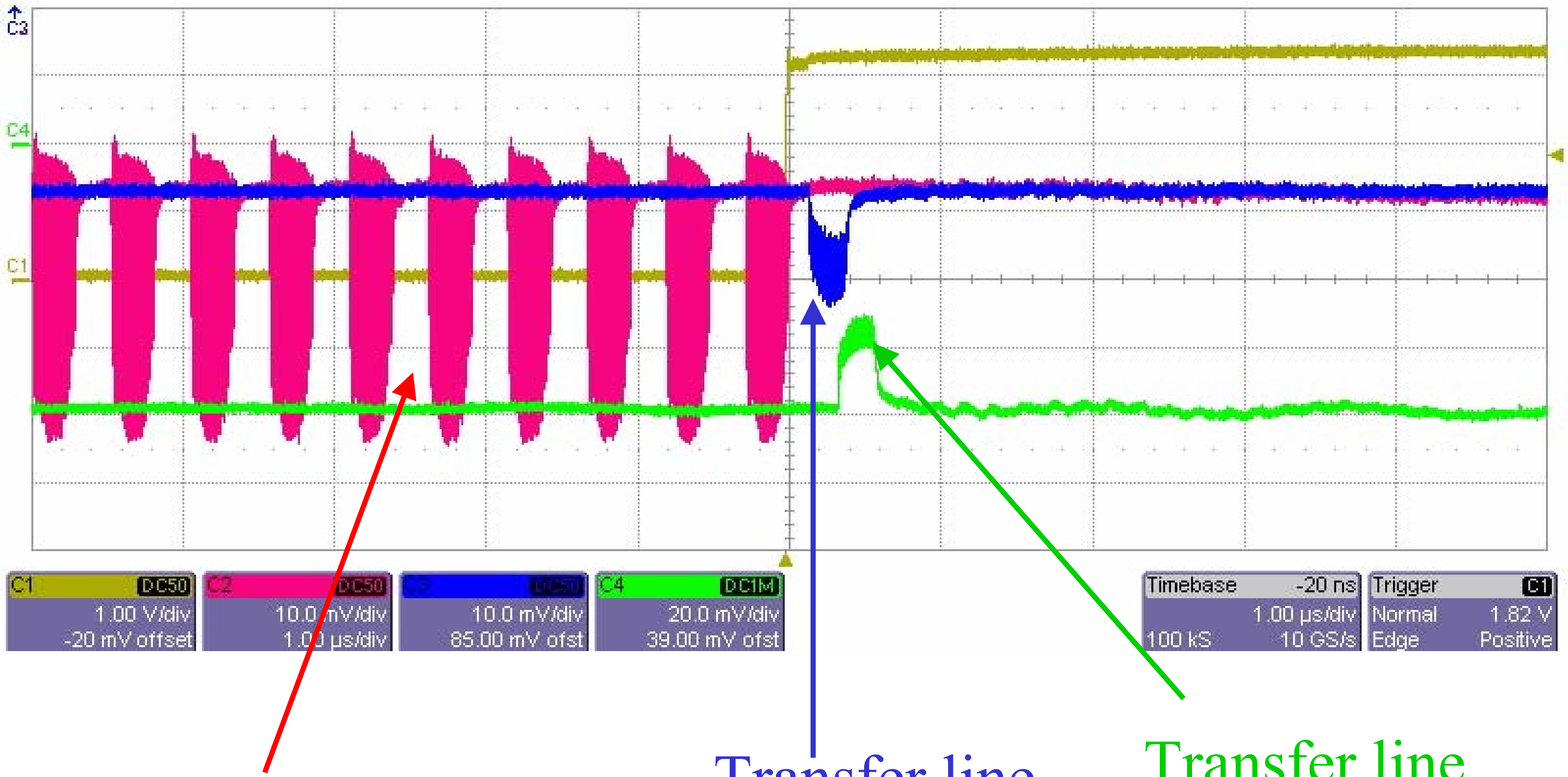


Beam decelerated down to 140 MeV

THPLS008
A. Loulergue

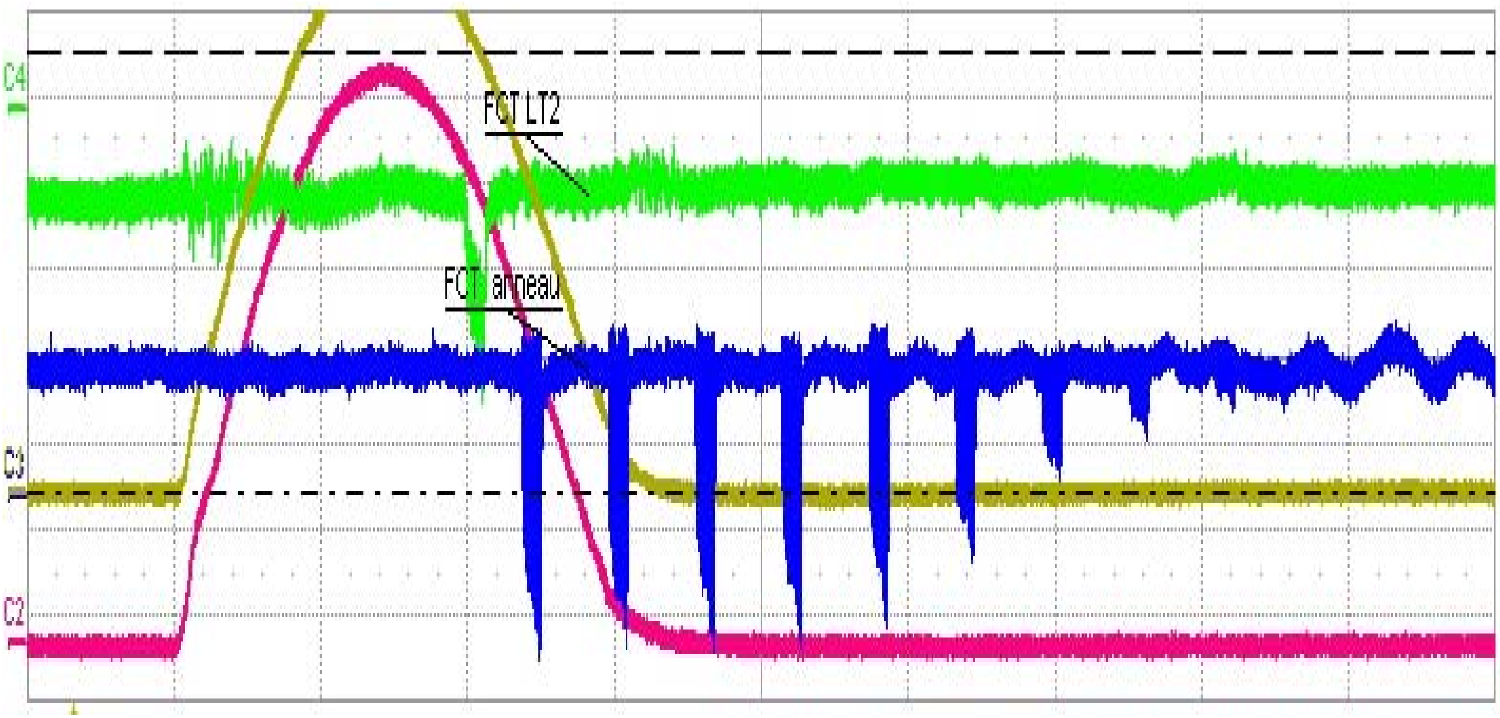
Booster : 1st extraction of 2.75 GeV beam

May 6th



Storage Ring Commissioning

May 14, 2 am : THE VERY FIRST TURNS (9)
(without any trajectory correction)



The beam went through the 10 small aperture chambers !!

THPLS009
A. Nadji

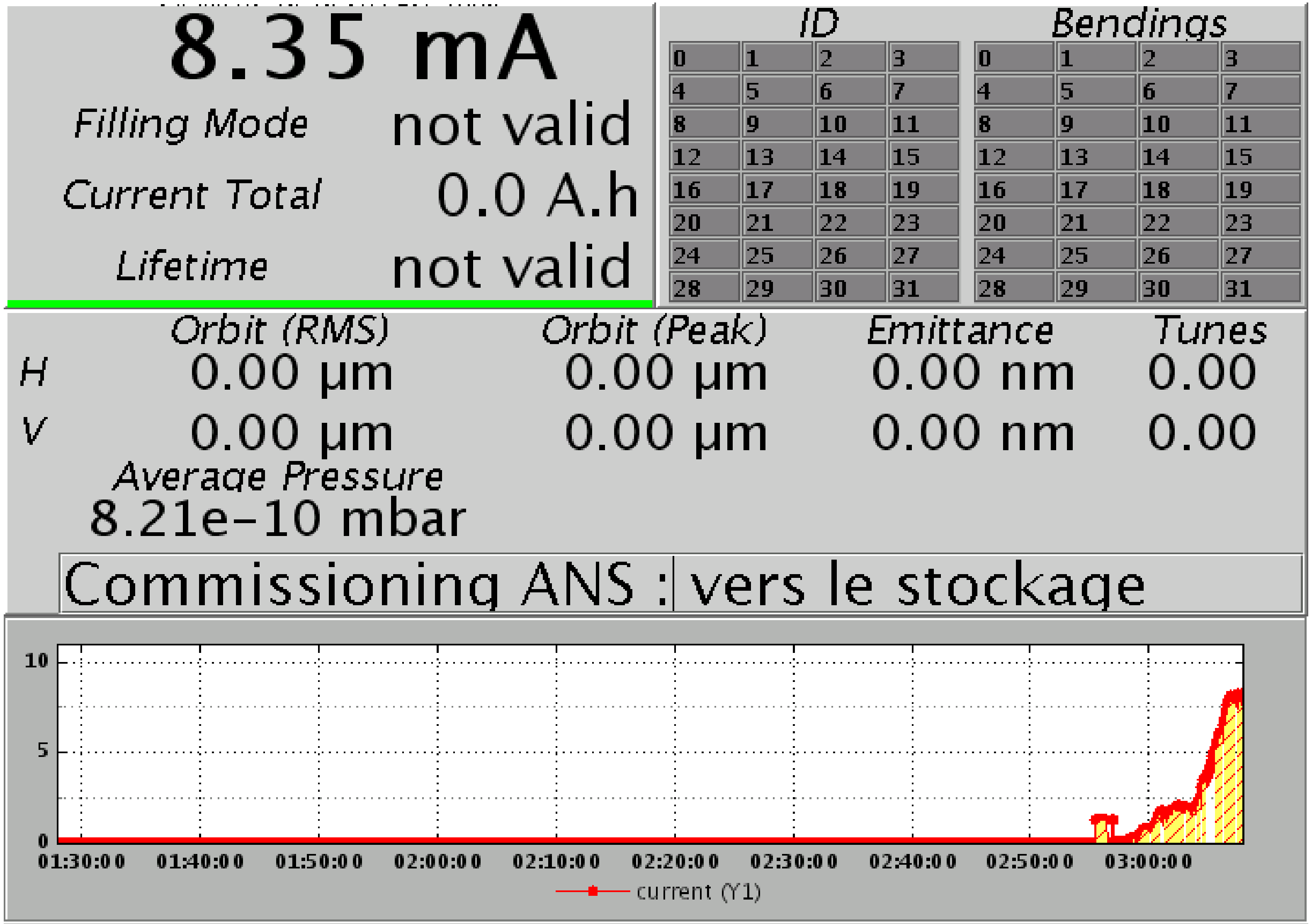
Start of radiation measurements (May 14, May 20, May 31)

Storage Ring Commissioning

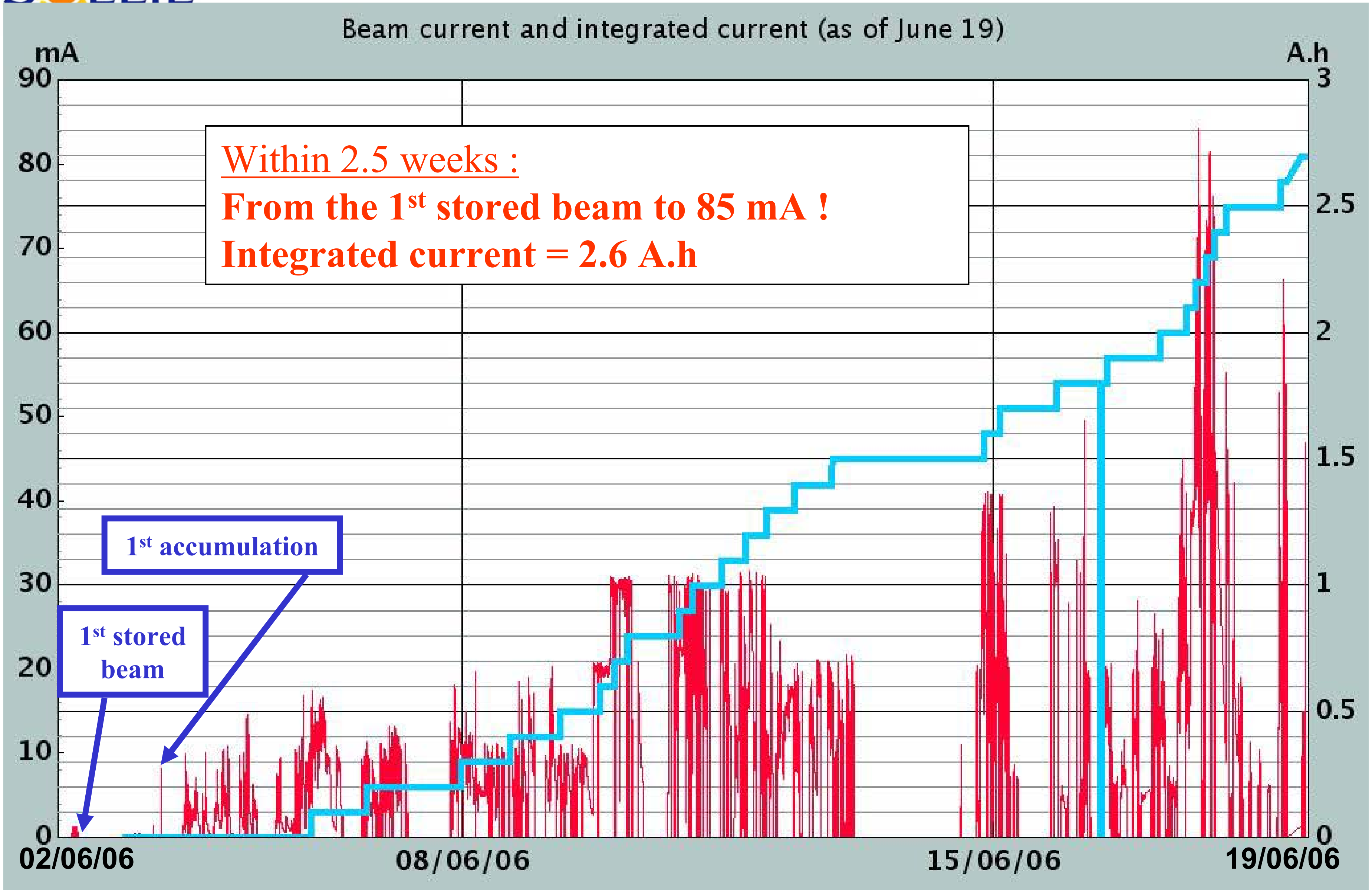
1st beam storage (0.3 mA) on June 2nd at 2 am !

Storage Ring Commissioning

1st beam accumulation (8 mA) on June 4th at 3 am !



Storage Ring Commissioning

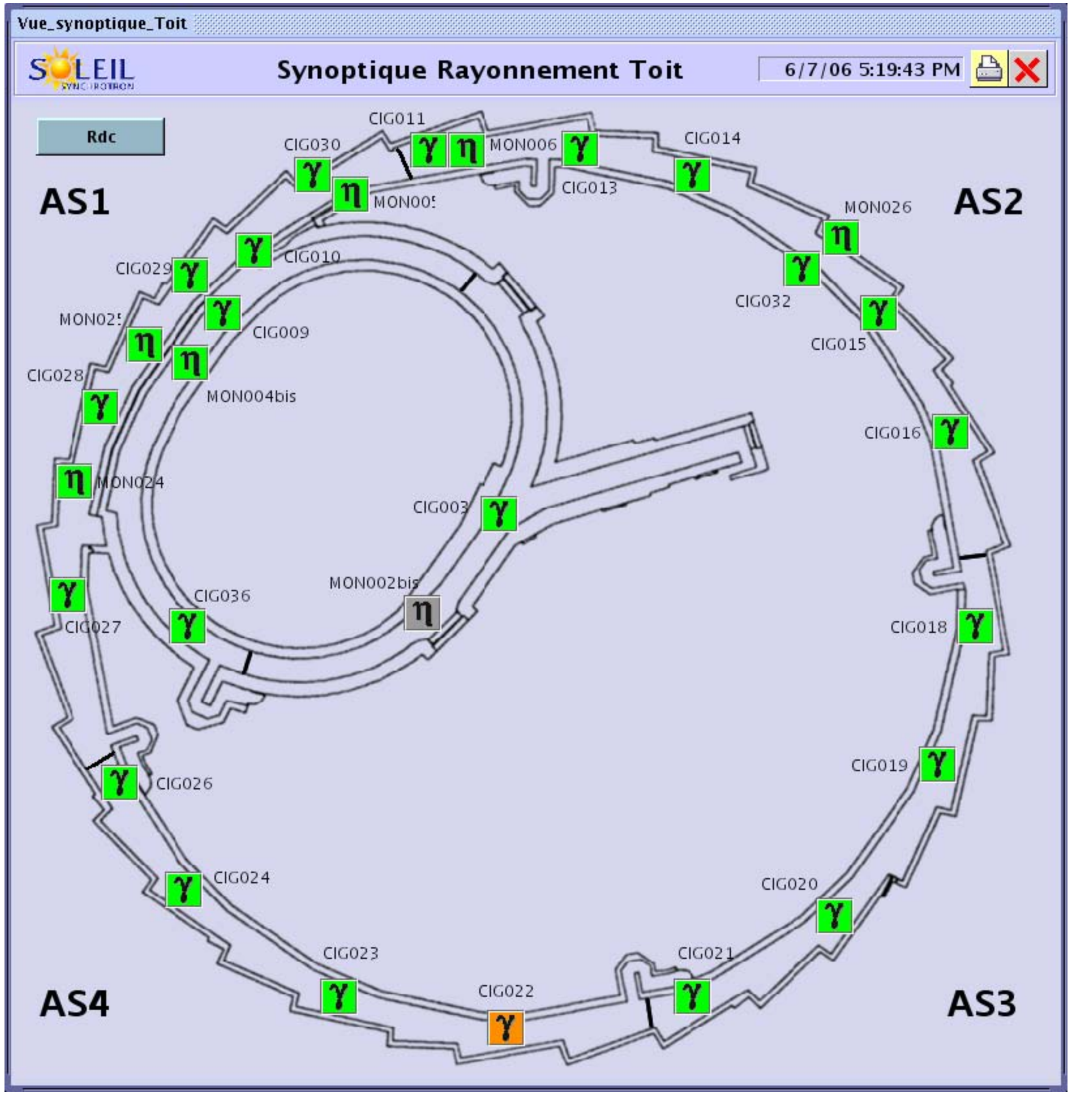


Storage Ring Commissioning

Continuous Injection during radiation controls

Radiation monitoring

A set of radiation monitors are distributed around the tunnels (34 γ and 28 n)



The maximum dose over 4 hours should not exceed 2 µSv

=> Strong constraints during commissioning time

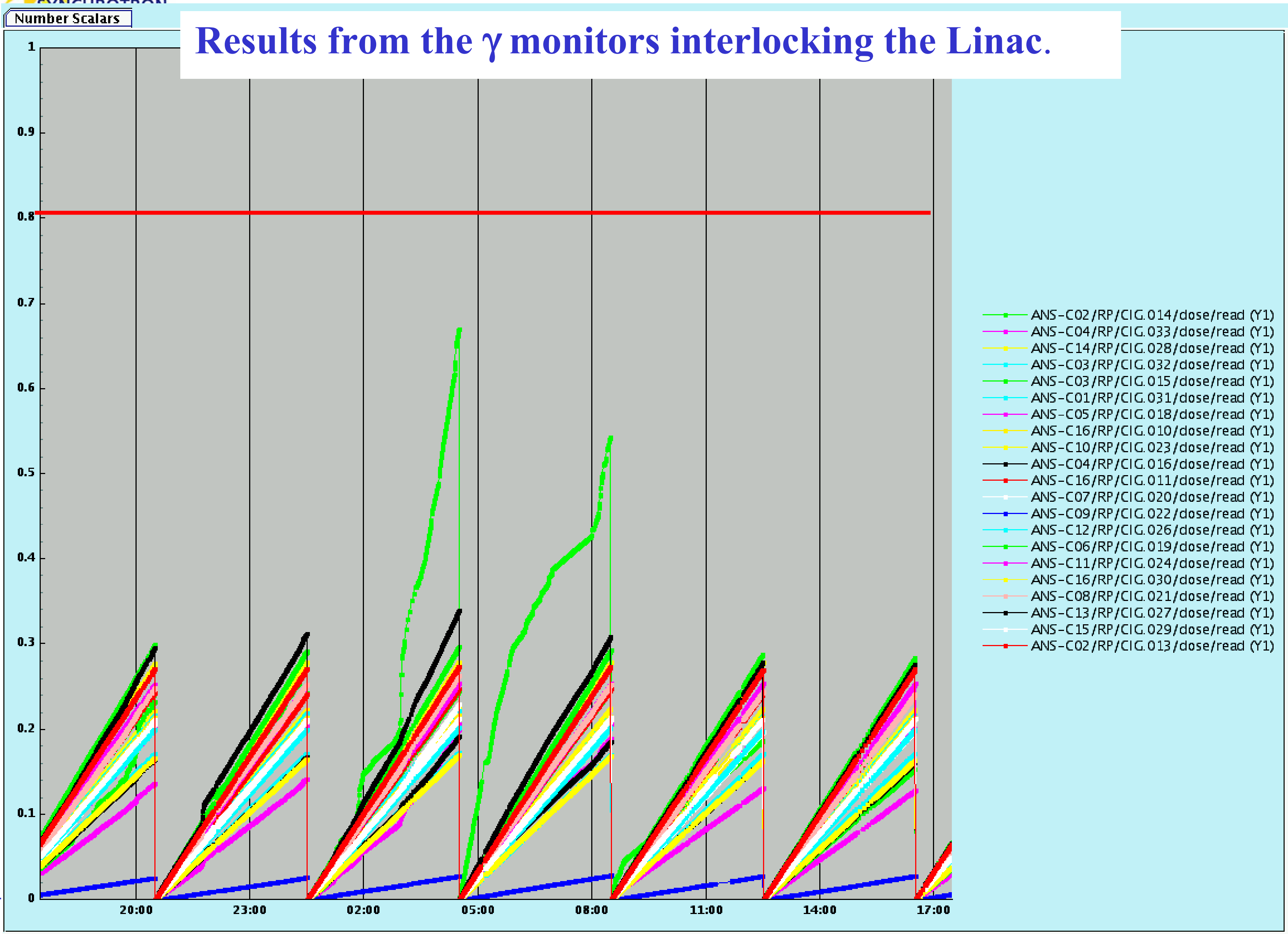
=> We managed to achieve it, thanks to the **very flexible synchronization system** :

=> Linac pulse at any frequency from 3 shots/s down to one shot on demand

=> Very low activation level inside the tunnels

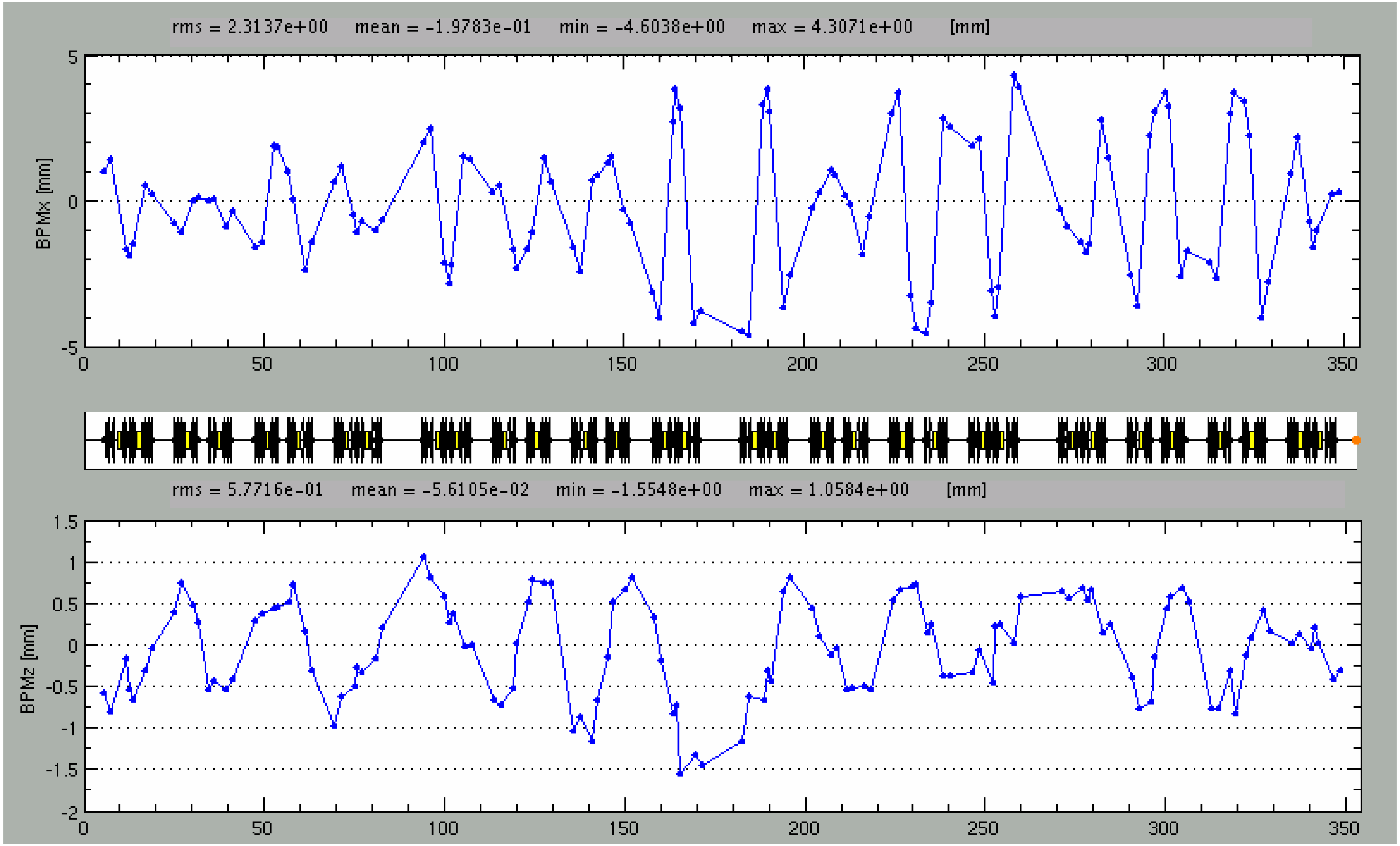
Radiation monitoring

Results from the γ monitors interlocking the Linac.



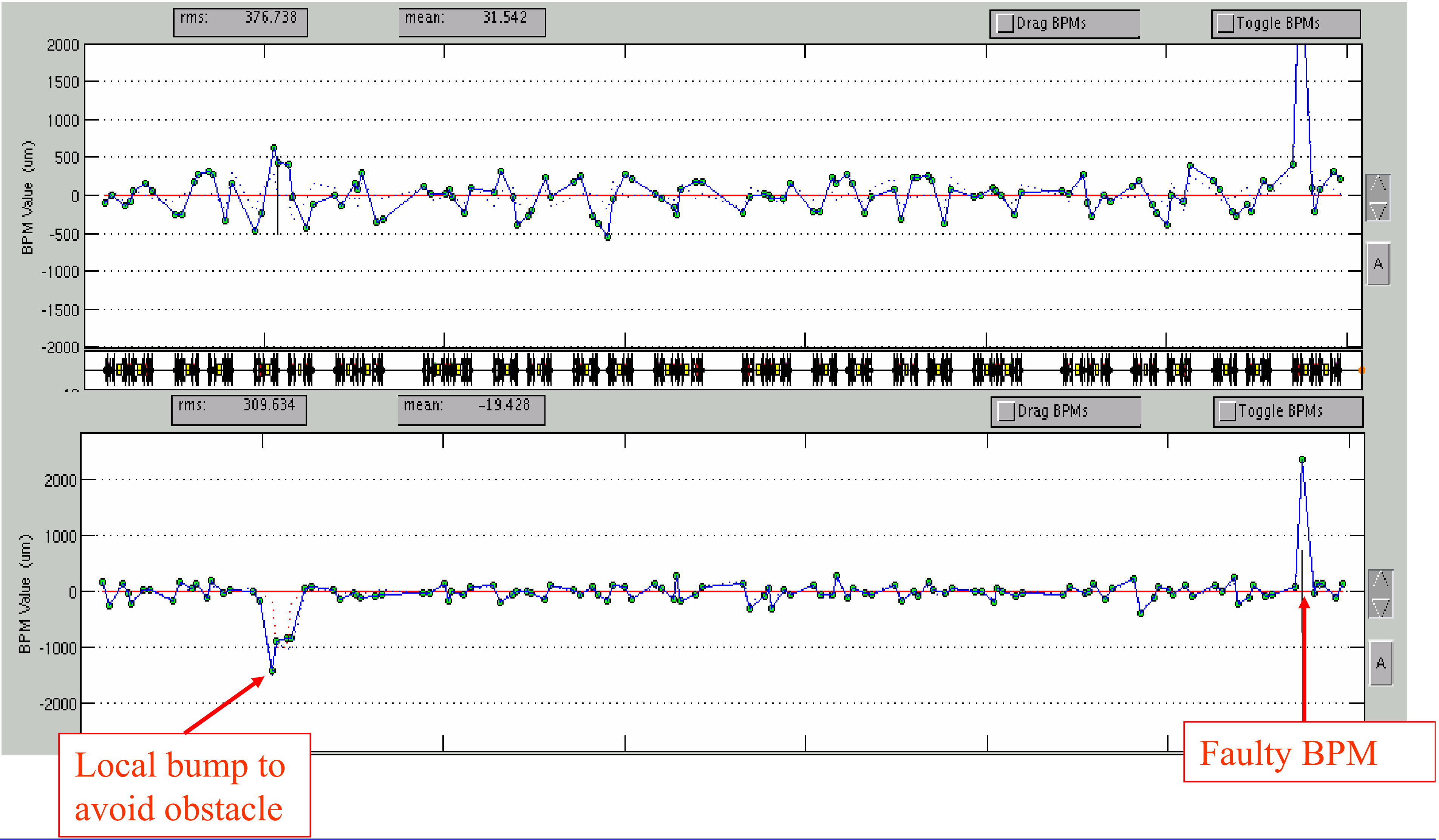
Storage Ring Commissioning

Uncorrected closed orbit errors : rmsH = 2.31 mm, rmsV = 0.58 mm

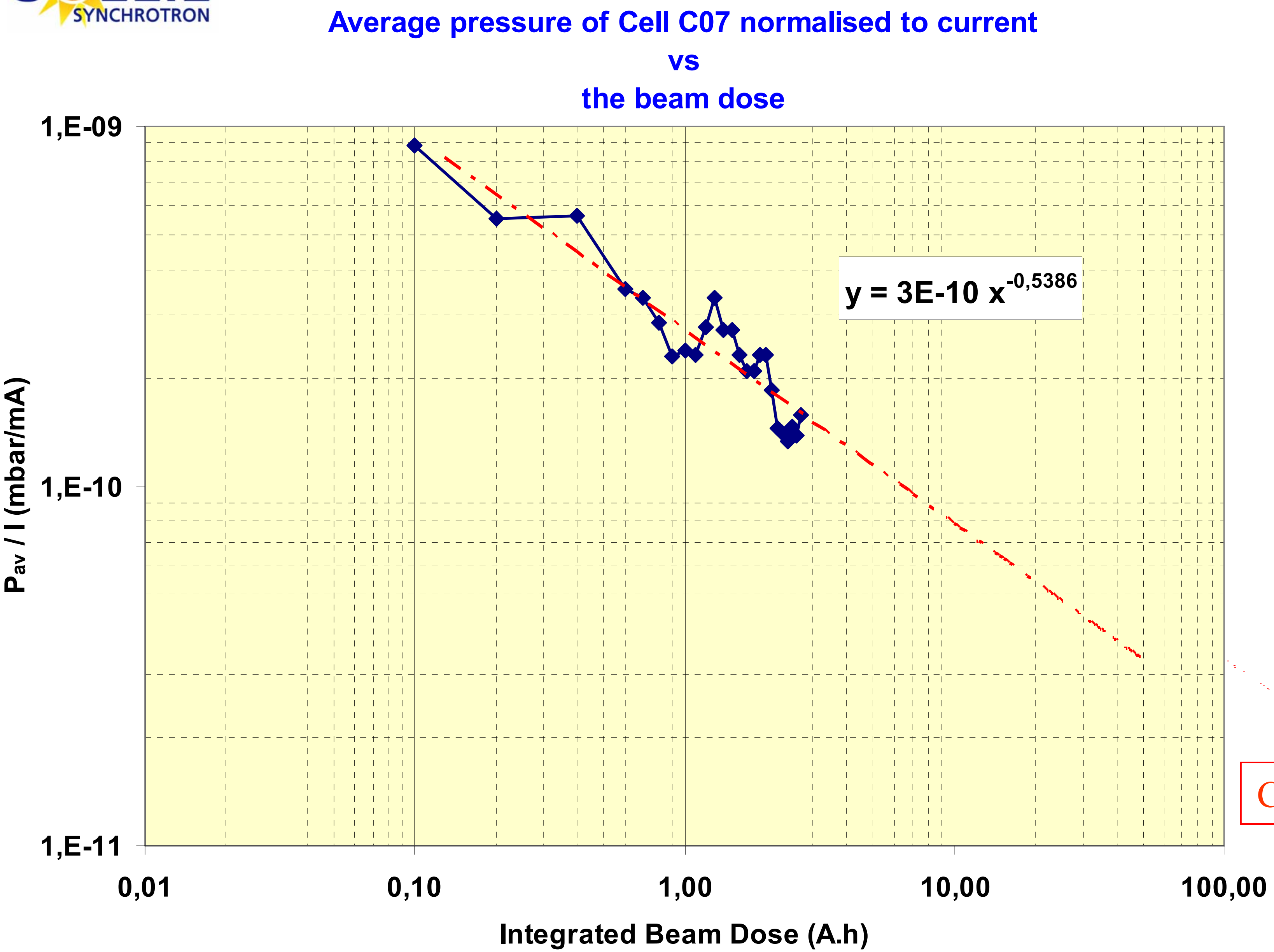


Storage Ring Commissioning

After correction : rmsH = 0.38 mm, rmsV = 0.31 mm

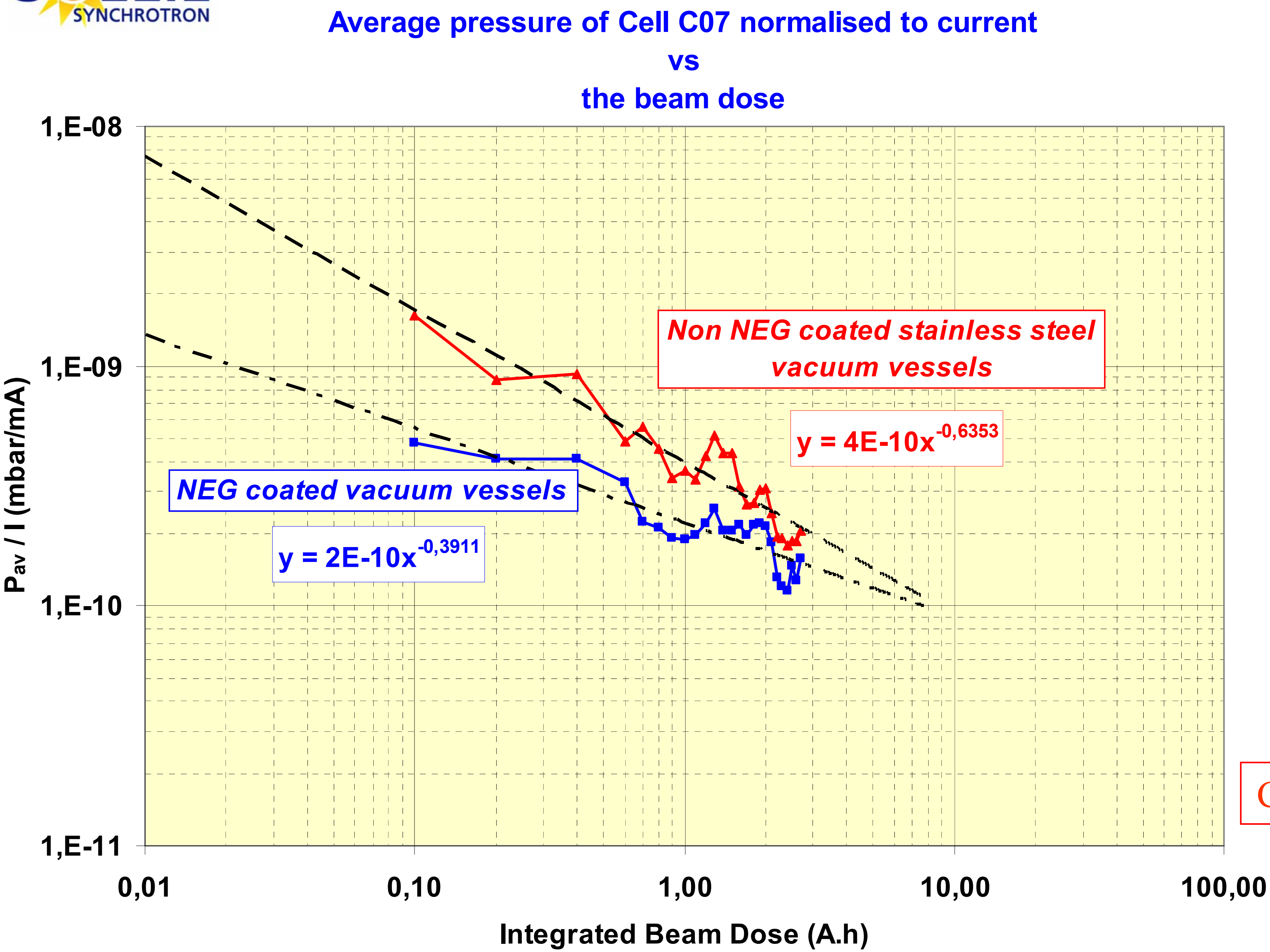


Vacuum conditioning



C. Herbeaux

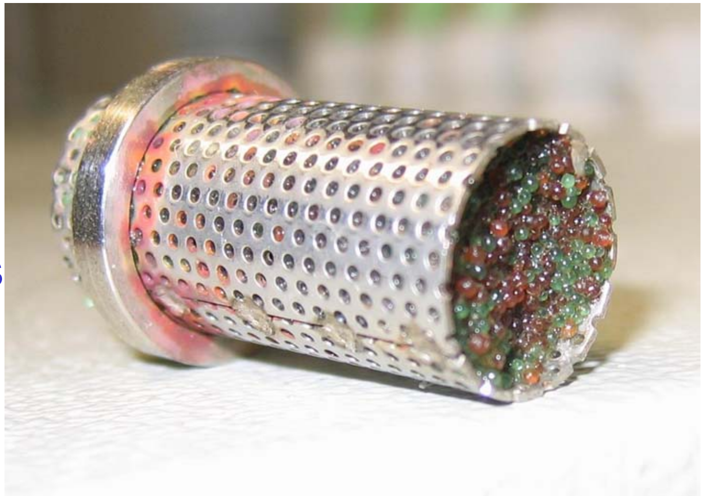
Vacuum conditioning



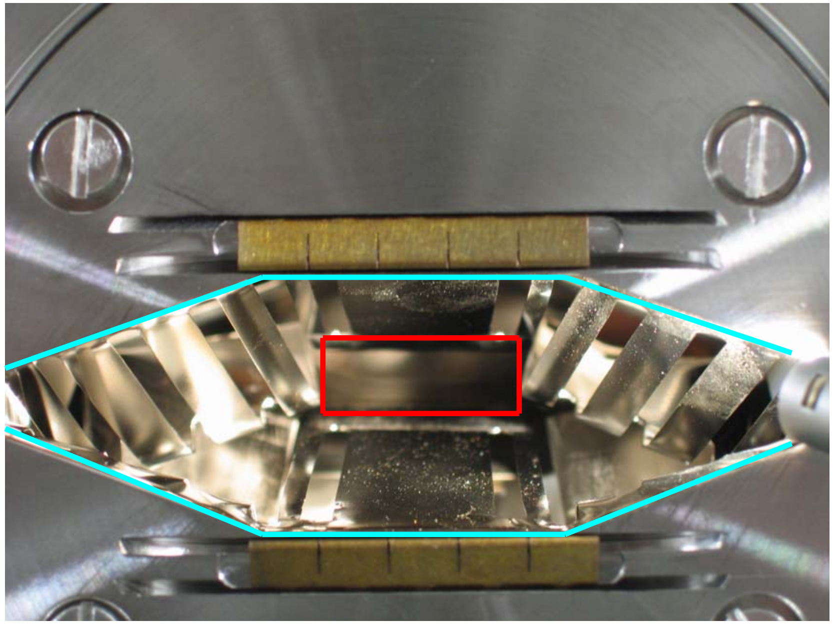
C. Herbeaux

Few problems

- **Problem of reduced flow due to small resin balls contaminating the water cooling circuit due to a human mistake**
  - ⇒ Blocking of the filters on the magnets
  - ⇒ Blocking of the filters on some power supplies
  - ⇒ Blocking of the crotch cooling circuits
  - ⇒ Cleaning of the whole network during this summer



- **Problem of obstacle reducing the beam stay clear aperture**
  - ⇒ Bad mounting of 2 RF Finger assemblies (out of ~200)
  - ⇒ Will all be checked during this summer



Conclusions

Smooth and efficient start-up of the commissioning

- All diagnostics required were available on time
- The TANGO Machine control system worked nicely

- Excellent machine alignment

- Vacuum conditioning in good progress
- But present current limitations possibly due to Fast Ion instabilities ?

THPCH032
R. Nagaoka

- **Present performances are very promising**

Our present goal is to reach 100 mA usable by the beamlines

The delivery of photon beam for the commissioning of the beamlines will start in September 2006

The construction SOLEIL is completed.

SOLEIL has largely benefited from the Experience and expertise of the other labs.

We believe that SOLEIL has in return brought some significant contributions to the accelerator technologies