

# **SOLEIL Current Performances And Futur Developments**

**Amor Nadji**

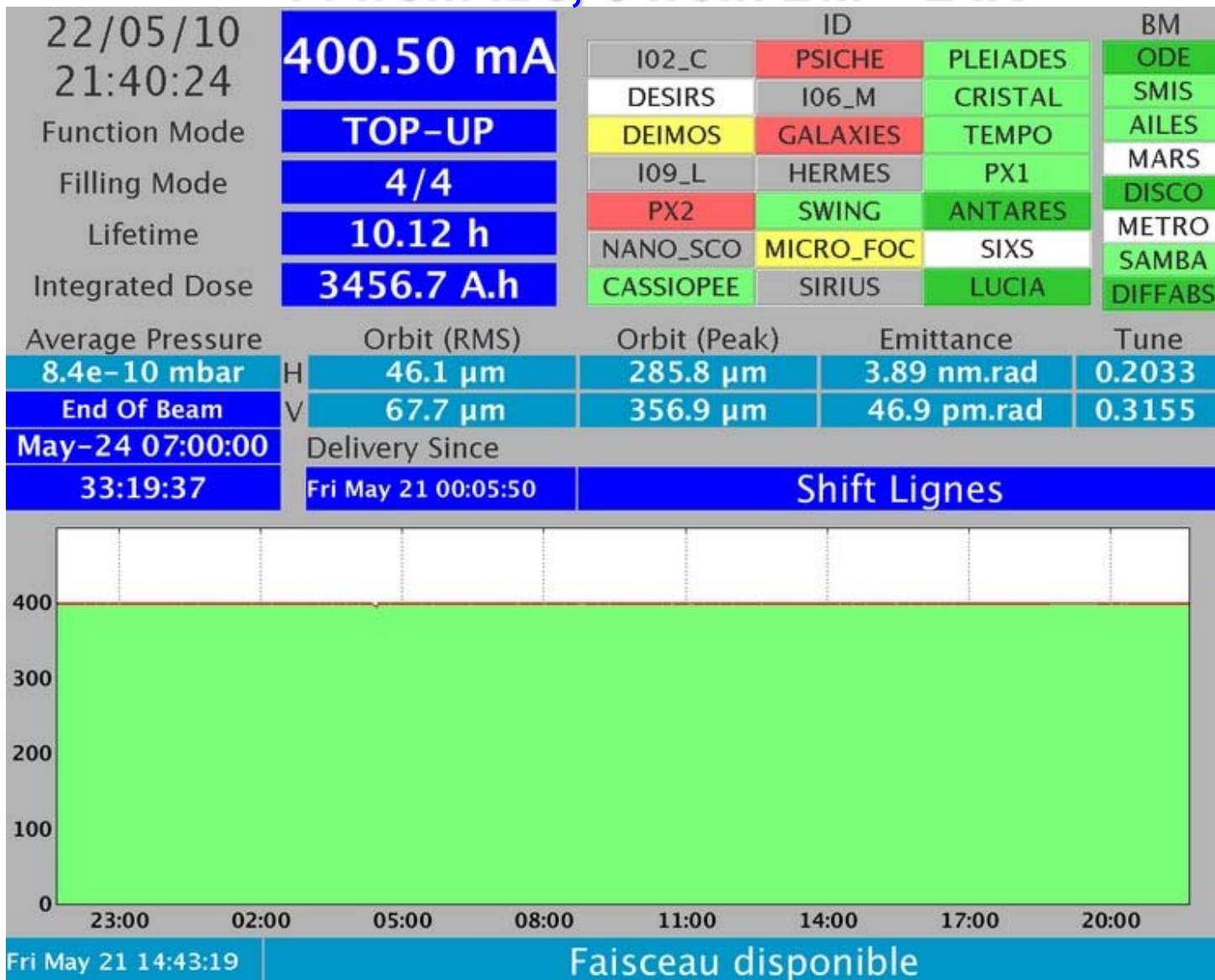
**On Behalf of the SOLEIL Team**

# Main Parameters

Energy (GeV)	2.75
Emittance H (nm.rad)	3.7 0.2
Coupling, $\epsilon_V/\epsilon_H$ (%)	Minimum achieved = 0.11 Operation $\approx 1 - 1.4$
Energy Spread	$1.0 \times 10^{-3}$
Betatron Tunes H / V	18.2020 / 10.3170
Chromaticities H / V	2 / 2.6
Multibunch Mode Current (mA)	500 (400 for users)
Average Pressure (mbar)	(< $1 \cdot 10^{-9}$ @ 500 mA); $7 \cdot 10^{-10}$ @ 400 mA
Beam Lifetime (h) @ 400 mA	11 - 18 depending on the IDs configuration
Single Bunch Current (mA)	20 (11 for users)

# 22 Beamlines are taking Photons

## 14 from IDs, 6 from BM + 2 IR

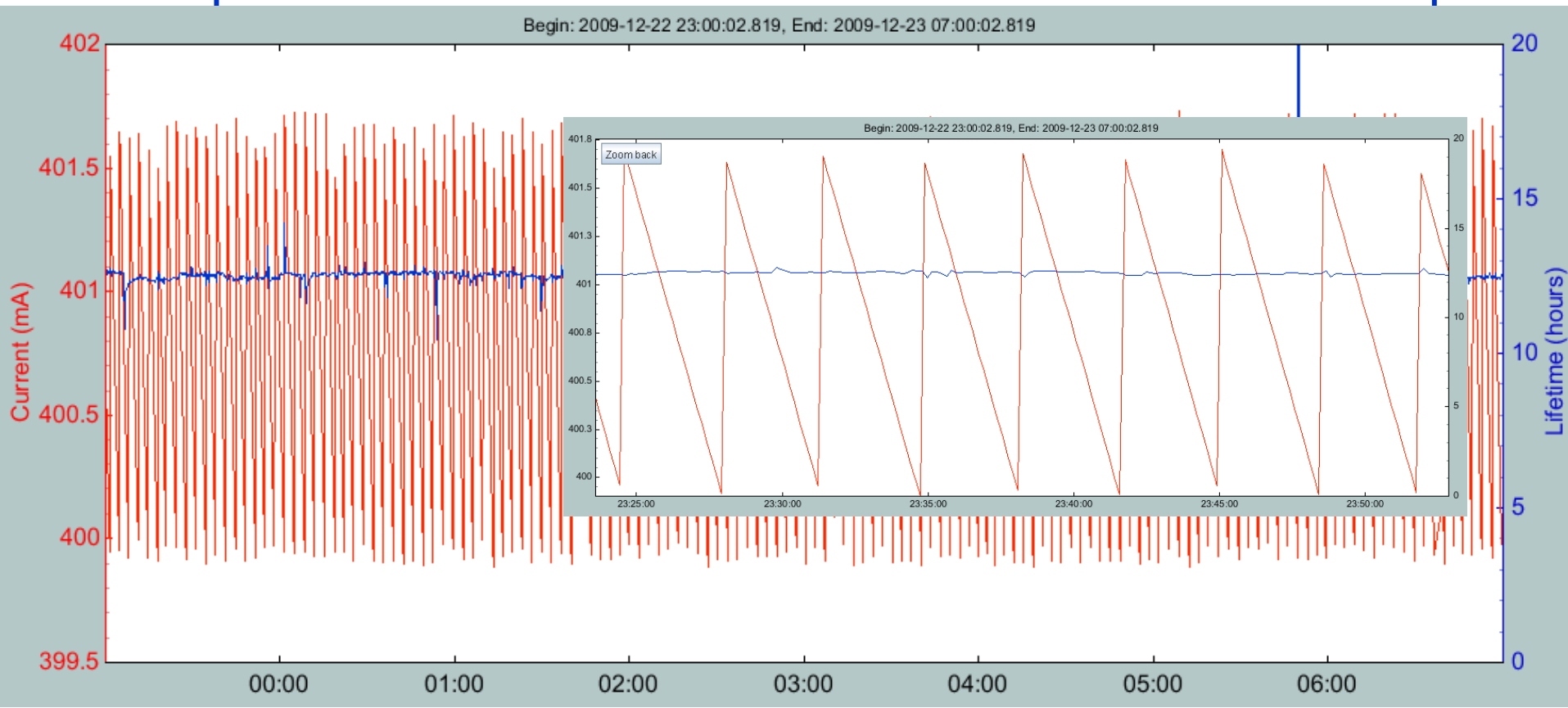


# Machine Operation: Top Up mode

$I = 400 \text{ mA} + 1.5 \text{ mA} \Rightarrow 0.4\% \text{ Current stability}$

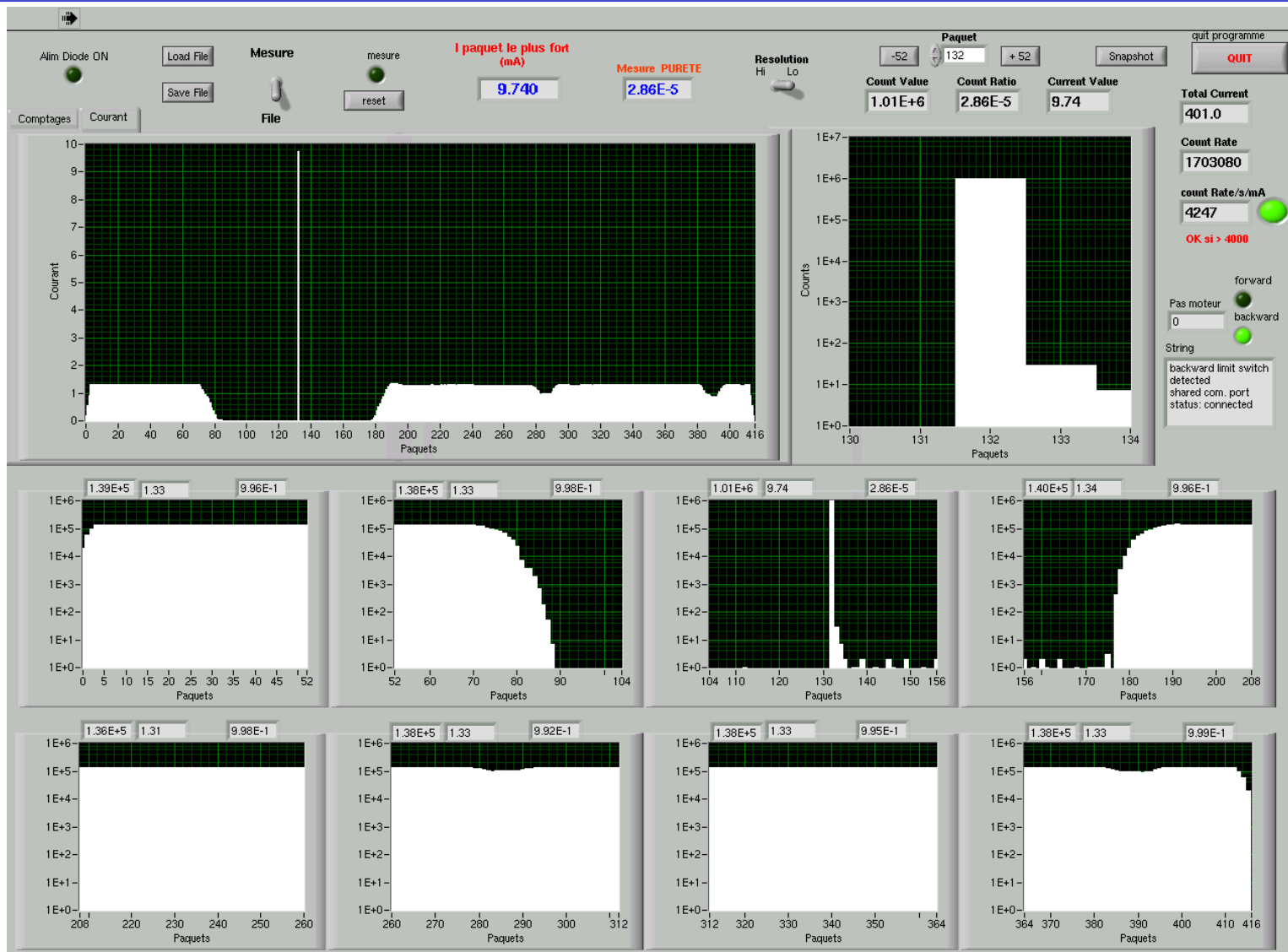
Lifetime  $\sim 11$  to  $18 \text{ h}$  (**uniform filling pattern**)

A single  $300 \text{ ns}$  Linac pulse of  $1.5 \text{ mA}$  is injected every  $3$  to  $5 \text{ mn}$

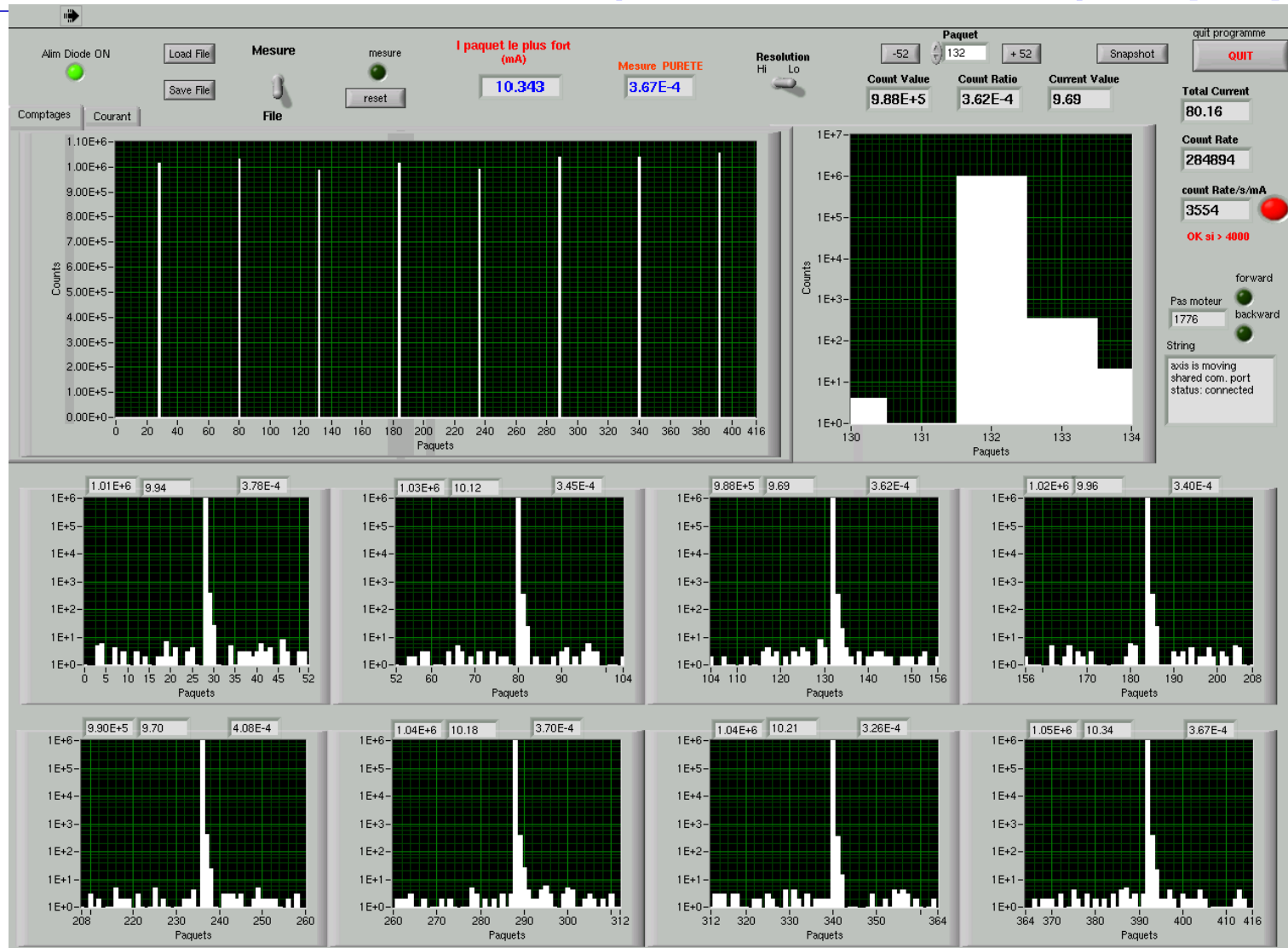


**Longest uninterrupted beam delivery reached 144 hours**

## Hybrid mode at 400 mA (392 mA + 8 mA), Top up.



## 8 bunch mode at 95 mA (Lifetime ~4 hours), Top up.



# 2010 Operation Schedule

janv 2010	févr 2010	mars 2010	avr 2010	mai 2010	juin 2010	juil 2010	août 2010	sept 2010	oct 2010	nov 2010	déc 2010	janv 2011											
ven 01	lun 01	m m m	lun 01	jeu 01	T T T	sam 01	m m m	mar 01	H H H	jeu 01	T T T	dim 01	mer 01	T T T	ven 01	T T T	lun 01	m m m	mer 01	T T T	sam 01	...	
sam 02	mar 02	p T T	mar 02	ven 02	T T T	dim 02	m m m	mer 02	H H H	ven 02	T T T	lun 02	jeu 02	T T T	sam 02	T T T	mar 02	8 8 8	jeu 02	T T T	dim 02	...	
dim 03	mer 03	T T T	mer 03	sam 03	T T T	lun 03	m m m	jeu 03	H H H	sam 03	T T T	mar 03	ven 03	T T T	dim 03	T T T	mer 03	8 8 8	ven 03	T T T	lun 03	...	
lun 04	jeu 04	T T T	jeu 04	dim 04	T T T	mar 04	T T T	ven 04	H H H	dim 04	T T T	mer 04	sam 04	T T T	lun 04	m m m	jeu 04	8 8 8	sam 04	T T T	mar 04	...	
mar 05	ven 05	T T T	ven 05	lun 05	m m m	mer 05	T T T	sam 05	H H H	lun 05	m m m	jeu 05	dim 05	T T T	mar 05	T T r	ven 05	8 8 8	dim 05	T T T	mer 05	...	
mer 06	sam 06	T T T	sam 06	mar 06	T T T	jeu 06	T T T	dim 06	H H H	mar 06	T T r	ven 06	lun 06	m m m	mer 06	T T T	sam 06	8 8 8	lun 06	m m m	jeu 06	...	
jeu 07	dim 07	T T T	dim 07	mer 07	T T T	ven 07	T T T	lun 07	m m m	mer 07	T T T	sam 07	mar 07	T T r	jeu 07	T T T	dim 07	8 8 8	mar 07	T T r	ven 07	...	
ven 08	lun 08	m m m	lun 08	jeu 08	T T T	sam 08	T T T	mar 08	8 8 8	jeu 08	T T T	dim 08	mer 08	T T T	ven 08	T T T	lun 08	m m m	mer 08	T T T	sam 08	...	
sam 09	mar 09	T T r	mar 09	ven 09	T T T	dim 09	T T T	mer 09	8 8 8	ven 09	T T T	lun 09	jeu 09	T T T	sam 09	T T T	mar 09	T T r	jeu 09	T T T	dim 09	...	
dim 10	mer 10	T T T	mer 10	sam 10	T T T	lun 10	m m m	jeu 10	8 8 8	sam 10	T T T	mar 10	ven 10	T T T	dim 10	T T T	mer 10	T T T	ven 10	T T T	lun 10	...	
lun 11	jeu 11	T T T	jeu 11	dim 11	T T T	mar 11	p T T	ven 11	8 8 8	dim 11	T T T	mer 11	sam 11	T T T	lun 11	m m m	jeu 11	T T T	sam 11	T T T	mar 11	...	
mar 12	ven 12	T T T	ven 12	m m m	lun 12	mer 12	T T T	sam 12	8 8 8	lun 12	m m m	jeu 12	dim 12	T T T	mar 12	S S S	ven 12	T T T	dim 12	T T T	mer 12	...	
mer 13	sam 13	T T T	sam 13	m m m	mar 13	jeu 13	T T T	dim 13	8 8 8	mar 13	T T r	ven 13	lun 13	m m m	mer 13	S S S	sam 13	T T T	lun 13	m m m	jeu 13	...	
jeu 14	dim 14	T T T	dim 14	m m m	mer 14	ven 14	T T T	lun 14	8 8 8	jeu 14	T T T	sam 14	mar 14	T T r	jeu 14	T T T	dim 14	T T T	mar 14	T T r	ven 14	...	
ven 15	lun 15	m m m	lun 15	m m m	jeu 15	ven 15	T T T	lun 15	8 8 8	ven 15	T T T	sam 15	mar 15	T T r	jeu 15	T T T	lun 15	m m m	mer 15	T T T	sam 15	...	
sam 16	mar 16	T T r	mar 16	T T r	ven 16	lun 16	T T T	mer 16	8 8 8	lun 16	T T T	jeu 16	dim 16	T T T	mar 16	T T r	jeu 16	T T T	ven 16	T T T	dim 16	...	
dim 17	mer 17	T T T	mer 17	T T T	sam 17	lun 17	T T T	mer 17	8 8 8	mer 17	T T T	ven 17	lun 17	T T T	jeu 17	T T T	ven 17	T T T	lun 17	T T T	mar 17	...	
lun 18	jeu 18	T T T	jeu 18	T T T	dim 18	mer 18	T T T	ven 18	8 8 8	jeu 18	T T T	sam 18	mar 18	T T T	jeu 18	T T T	sam 18	T T T	mar 18	T T T	lun 18	...	
mar 19	ven 19	T T T	ven 19	T T T	lun 19	mer 19	T T T	ven 19	8 8 8	ven 19	T T T	dim 19	mer 19	T T T	jeu 19	T T T	dim 19	T T T	mer 19	T T T	lun 19	...	
mer 20	sam 20	T T T	sam 20	T T T	mar 20	jeu 20	T T T	ven 20	8 8 8	sam 20	T T T	lun 20	jeu 20	T T T	sam 20	T T T	lun 20	T T T	jeu 20	T T T	dim 20	...	
jeu 21	dim 21	T T T	dim 21	T T T	mer 21	ven 21	T T T	lun 21	8 8 8	dim 21	T T T	mer 21	jeu 21	T T T	dim 21	T T T	mar 21	T T T	ven 21	T T T	lun 21	m m m	
ven 22	m m m	lun 22	m m m	lun 22	m m m	jeu 22	T T T	ven 22	8 8 8	ven 22	T T T	sam 22	mar 22	T T T	lun 22	m m m	mer 22	...	sam 22	m m m	jeu 22	m m m	
sam 23	m m m	mar 23	S S S	mar 23	p T T	ven 23	T T T	mer 23	8 8 8	lun 23	T T T	jeu 23	dim 23	T T T	mar 23	T T r	jeu 23	...	dim 23	m m m	jeu 23	m m m	
dim 24	m m m	mer 24	S S S	mer 24	T T T	sam 24	...	lun 24	m m m	jeu 24	...	sam 24	T T T	mar 24	...	ven 24	T T T	dim 24	...	ven 24	...	lun 24	m m m
lun 25	m m m	jeu 25	S S S	jeu 25	T T T	dim 25	...	mar 25	T T T	ven 25	m m m	dim 25	T T T	mer 25	...	sam 25	T T T	lun 25	...	jeu 25	T T T	sam 25	1 1 1
mar 26	T T p	ven 26	S S S	ven 26	T T T	lun 26	...	mer 26	T T T	sam 26	m m m	lun 26	T T T	jeu 26	...	dim 26	T T T	mar 26	...	ven 26	T T T	dim 26	1 1 1
mer 27	T T T	sam 27	S S S	sam 27	T T T	mar 27	...	jeu 27	T T T	dim 27	m m m	mar 27	T T T	ven 27	m m m	lun 27	m m m	mer 27	...	sam 27	T T T	lun 27	1 1 1
jeu 28	T T T	dim 28	S S S	dim 28	T T T	mer 28	...	ven 28	T T T	jeu 28	...	dim 28	T T T	mer 28	...	sam 28	T T T	lun 28	...	jeu 28	...	ven 28	1 1 1
ven 29	T T T	lun 29	m m m	lun 29	m m m	jeu 29	...	ven 29	T T T	jeu 29	...	dim 29	T T T	mer 29	...	lun 29	m m m	lun 29	...	mer 29	...	sam 29	1 1 1
sam 30	T T T	mar 30	p T T	ven 30	T T T	ven 30	...	lun 30	m m m	jeu 30	...	dim 30	T T T	mer 30	...	mar 30	T T r	jeu 30	...	jeu 30	...	dim 30	1 1 1
dim 31	T T T	mer 31	T T T	mer 31	T T T	ven 31	...	lun 31	m m m	jeu 31	...	dim 31	T T T	mer 31	...	mar 31	T T T	ven 31	...	ven 31	...	lun 31	m m m

**4905 hours for the Beamlines**  
**1215 hours for the Machine Studies**  
**2640 hours for shut down**

**Plan for 2011:**  
**5208 hours for the Beamlines**  
**1200 hours for the Machine Studies**  
**2352 hours for shut down**

# Machine Operation

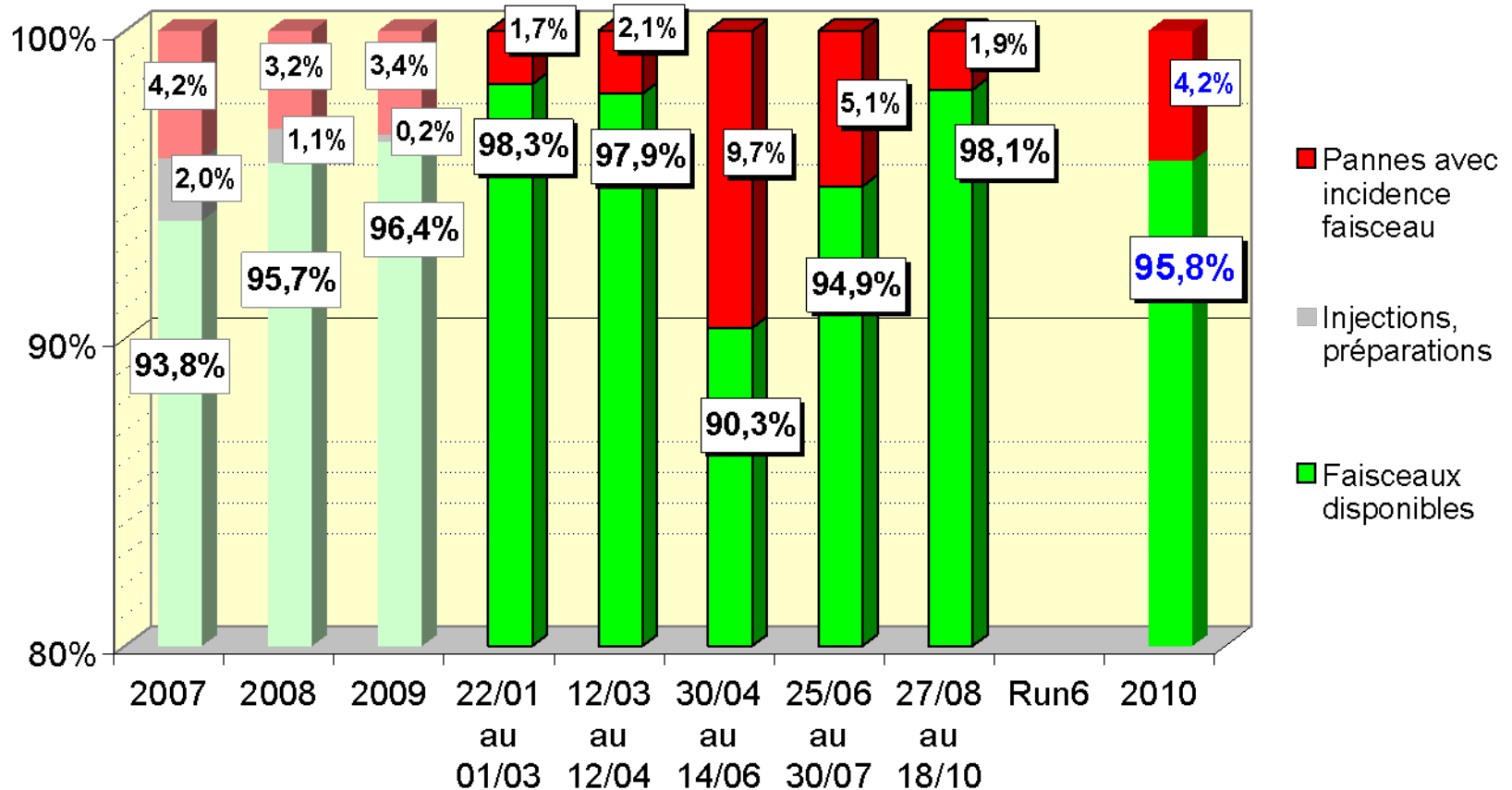
## Good progression in the availability of the beam

95.7% in 2008 (3 882 hours del.)

96.4% in 2009 (4 423 hours del. over 4588 h as scheduled)

97.3% from June 2009 till April 2010 (3858 h)

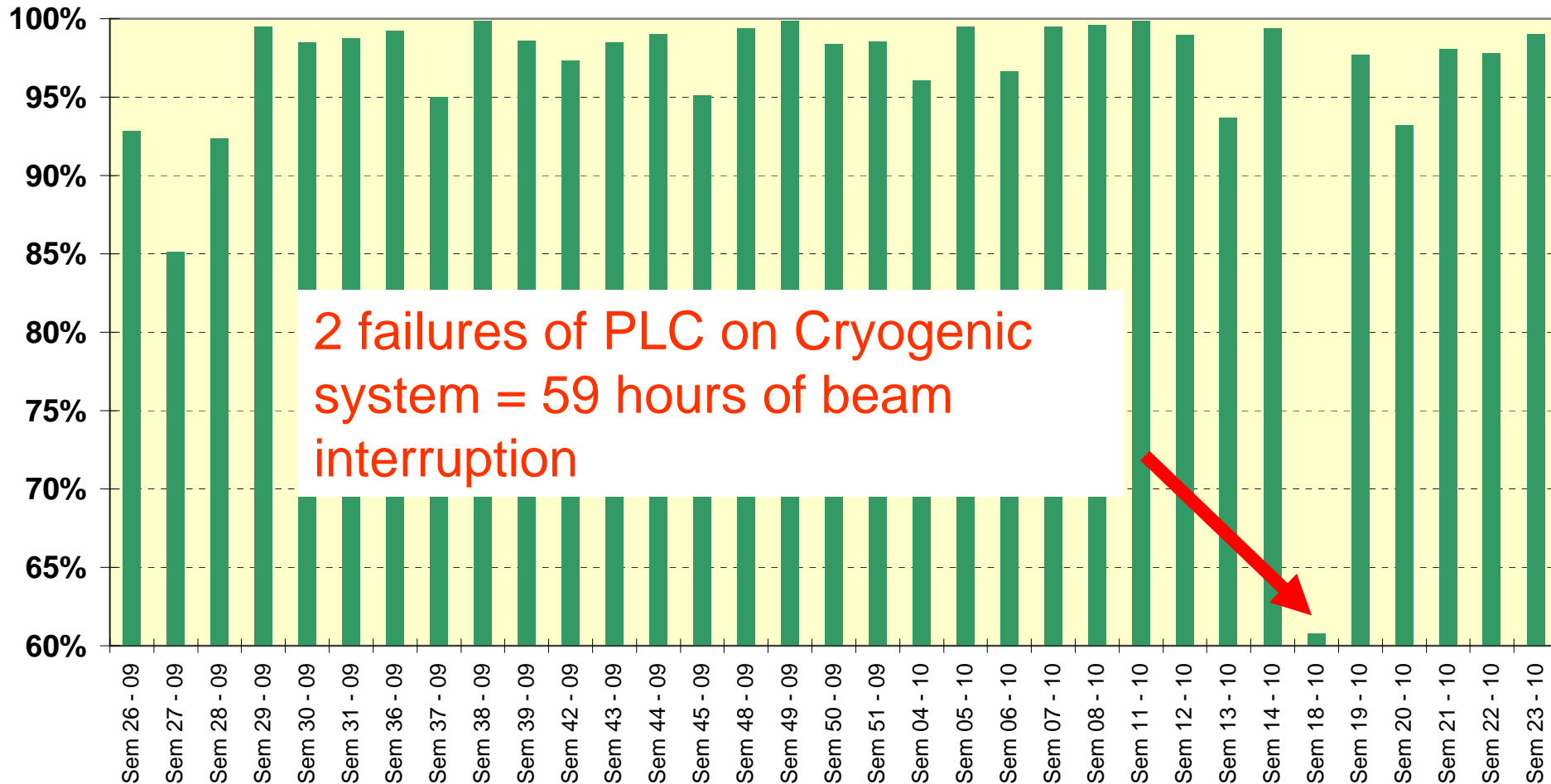
96.1% in 2010 (4115 hours del. as of 22 November 2010)





# Machine Operation

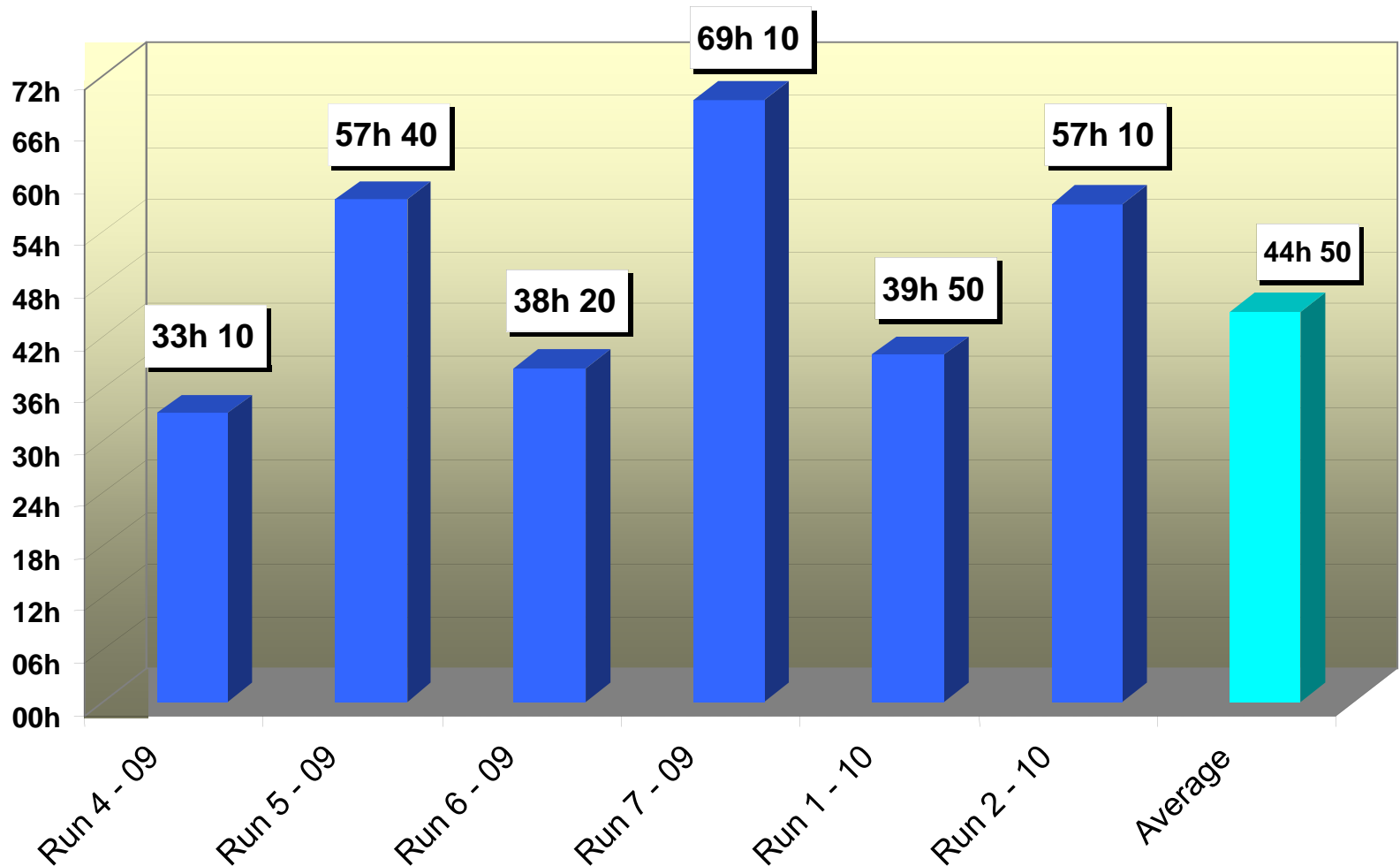
Beam availability on a weekly basis from June 2009 till June 2010



**recently 2 weeks with 100% availability!**

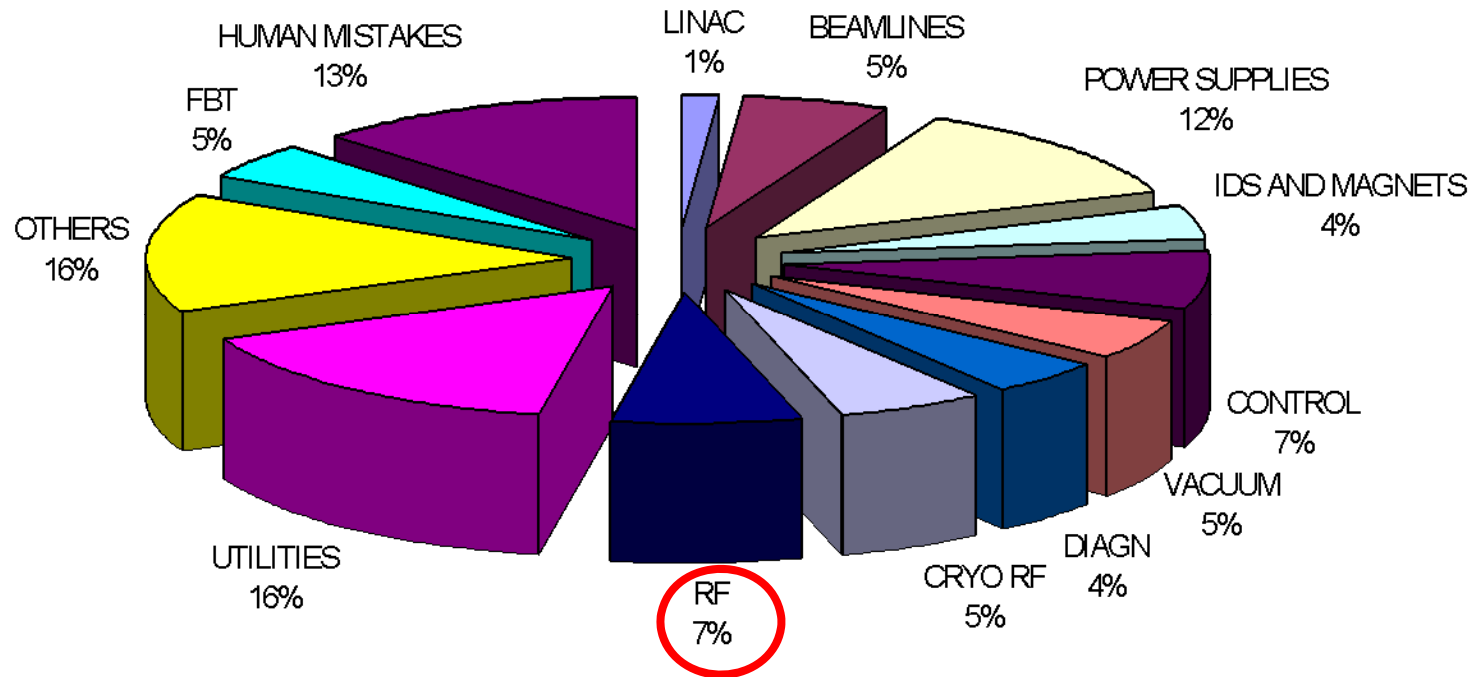
# Machine Operation

Mean Time Between Failure = 45 h over 3858 hours  
from June 2009 till April 2010



# Machine Operation

Beam time lost due to failures of equipment.  
The total time lost reached 156 hours over 2009.

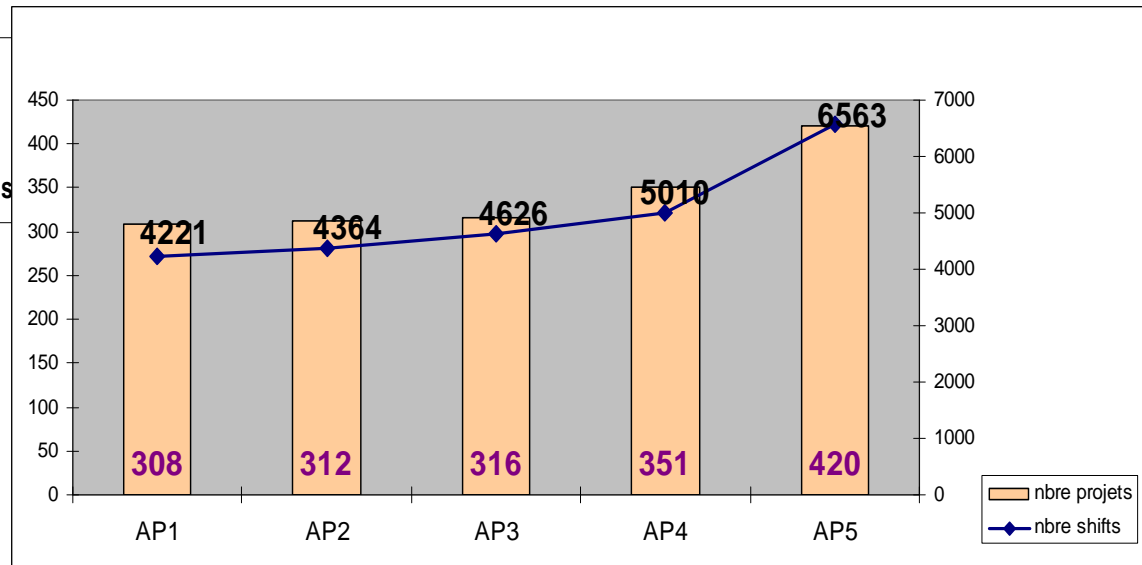
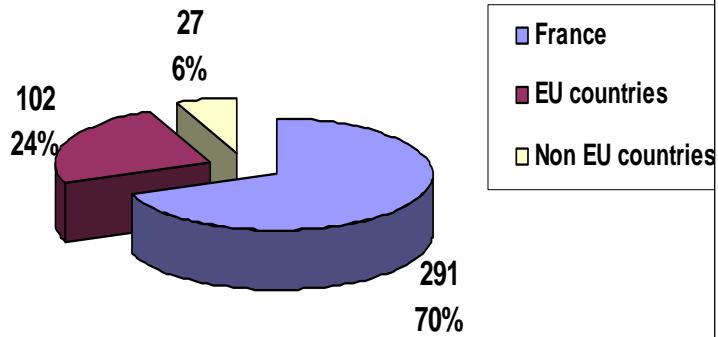


## AP5- Jan - July 2010

### The request is beyond the offer!

Number of shifts (8h) requested: **6563**

Number of shifts allocated: **2225**



# Insertion Devices

Beamline Name	Ring Location	Photon Energy	Source Type	Useful length (m)	Polarization	Technology
<b>Already installed on the ring</b>						
DESIRS	I 05-L	5 – 40 eV	HU640	10	Circ./lin/phasevar	HU640
CASSIOPEE #1	I 15-M	10 – 1000 eV	HU256	3,1	Circ./lin.	HU256
PLEIADES #2	I 04-M	10 – 1000 eV	HU256	3,1	Circ./lin.	HU256
ANTARES #1	I 12-M	10 – 1000 eV	HU256	3,1	Circ./lin.	HU256
PLEIADES #1	I 04-M	35 – 1500 eV	HU80*	1,6	Circ./lin.	APPLE II
TEMPO #1	I 08-M	45 – 1500 eV	HU80	1,6	Circ./lin.	APPLE II
SEXTANT #1	I 14-M	45 – 1500 eV	HU80	1,6	Circ./lin.	APPLE II
CASSIOPEE #2	I 15-M	100 eV – 4 keV	HU60	1,6	Circ./lin.	APPLE II
ANTARES #2	I 12-M	100 eV – 4 keV	HU60	1,6	Circ./lin.	APPLE II
DEIMOS #1	I 07-M	500 eV – 6 keV	HU52	1,6	Circ./lin.	APPLE II
LUCIA	I 16-M	500 eV – 6 keV	HU52	1,6	Circ./lin.	APPLE II
TEMPO #2	I 08-M	1 – 5 keV	HU44	1,6	Circ./lin.	APPLE II
SEXTANT #2	I 14-M	1 – 5 keV	HU44	1,6	Circ./lin.	APPLE II
SIRIUS	I 15-C	2 – 12 keV	HU36	1,6	Circ./lin.	APPLE II
PROXIMA1	I 10-C	4 – 30 keV	U20	1,96	Lin.	Hybrid in vacuum
SWING	I 11-C	4 – 30 keV	U20	1,96	Lin.	Hybrid in vacuum
CRISTAL	I 06-C	4 – 30 keV	U20	1,96	Lin.	Hybrid in vacuum
SIXS	I 14-C	4 – 30 keV	U20	1,96	Lin.	Hybrid in vacuum
GALAXIES	I 07-C	4 – 30 keV	U20	1,96	Lin.	Hybrid in vacuum
PROXIMA2	I 11-M	5 – 20 keV	U24	1,96	Lin.	Hybrid in vacuum
PSICHE	I 03-C	10 – 50 keV	WSV50	2	Lin.	Wiggler in vacuum
<b>Under construction</b>						
DEIMOS #2	I 07-M	350 – 900 eV	HU65	1,6	Circ./lin.	EMPHU
NanoScopium	I 13-L	4 – 30 keV	U20	1,96	Lin.	Hybrid in vacuum
Prototype		4 – 30 keV	U18	2,0	Lin.	CPMU
<b>Under design</b>						
HERMES #1	I 10-M	100 eV – 2 keV	HU64	1,6	Circ./lin.	APPLE II
HERMES #2	I 10-M	1.5 – 3 keV	HU40	1,6	Circ./lin.	APPLE II
PUMA/SLICING	I 06-M	15 – 60 keV	W164	3,0	Lin.	Wiggler PPM

21 installed on the SR

3 under construction

4 under design

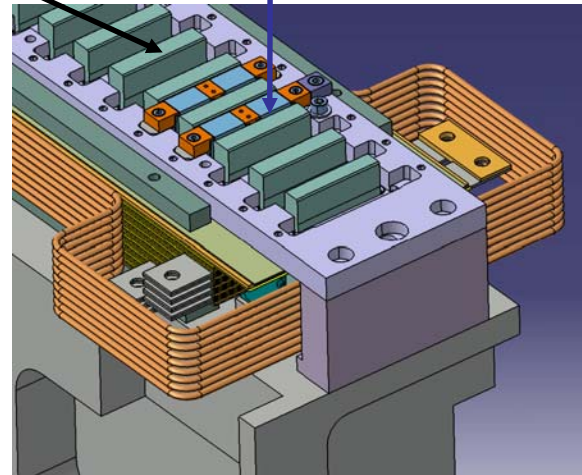
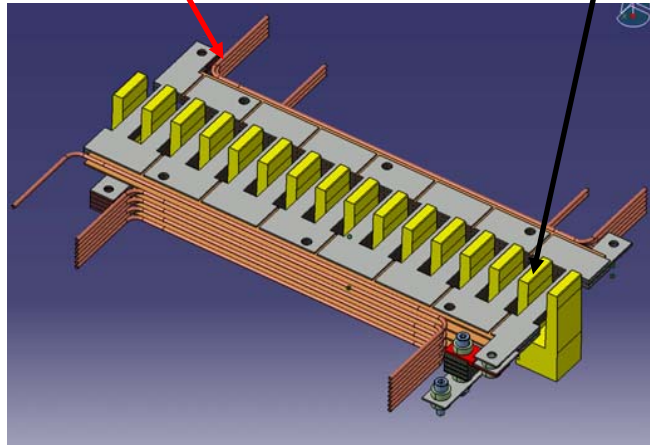
## EMPHU

Polarisation switching in 60 ms

Cu foils  $\leftrightarrow$  coils :  $B_z$

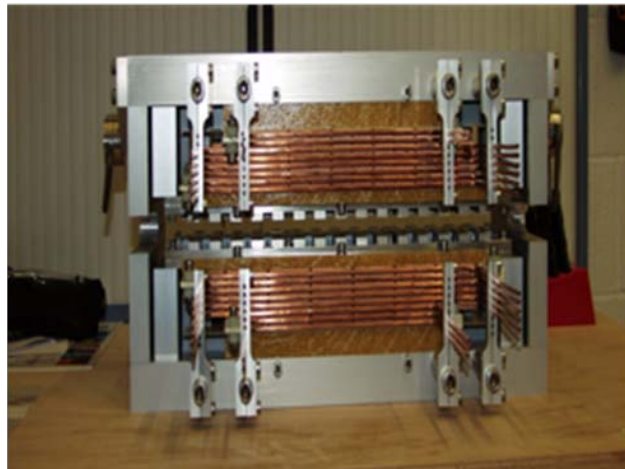
Steel : core and poles

Permanent magnets :  $B_x$



$B_x = B_z = 0.24 \text{ T}$

Prototype (SEF)

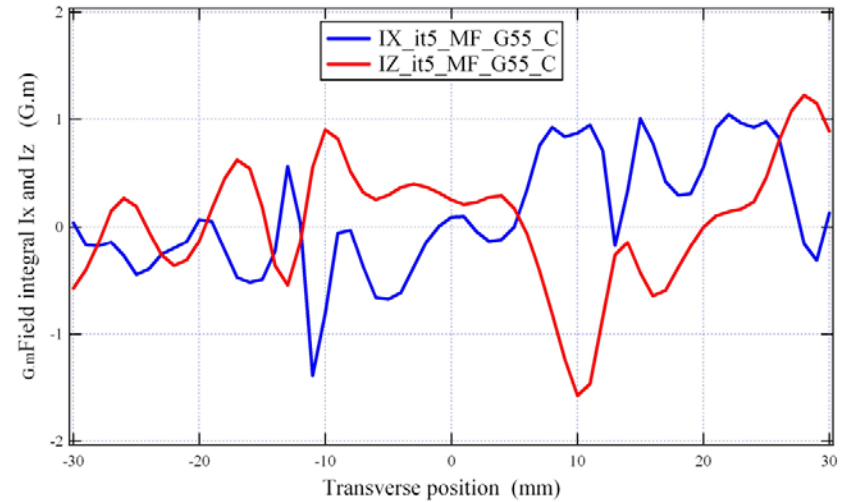
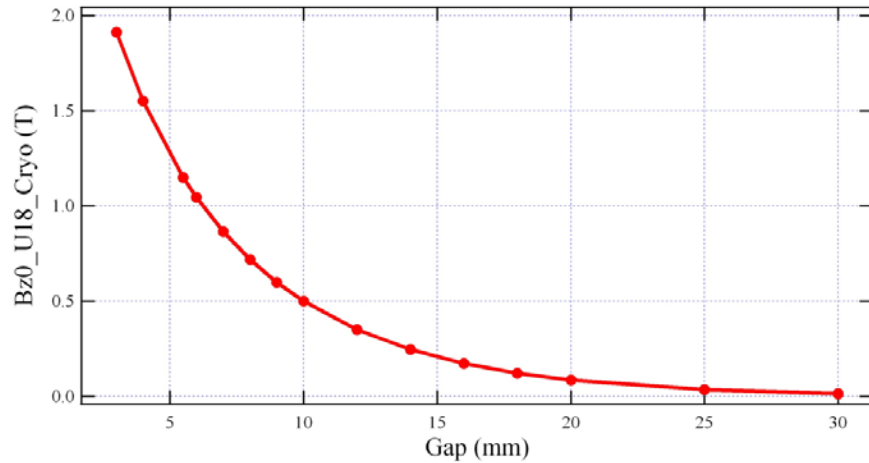


# R&D activities and future plans: Cryogenic Undulator

with PrFeB magnets

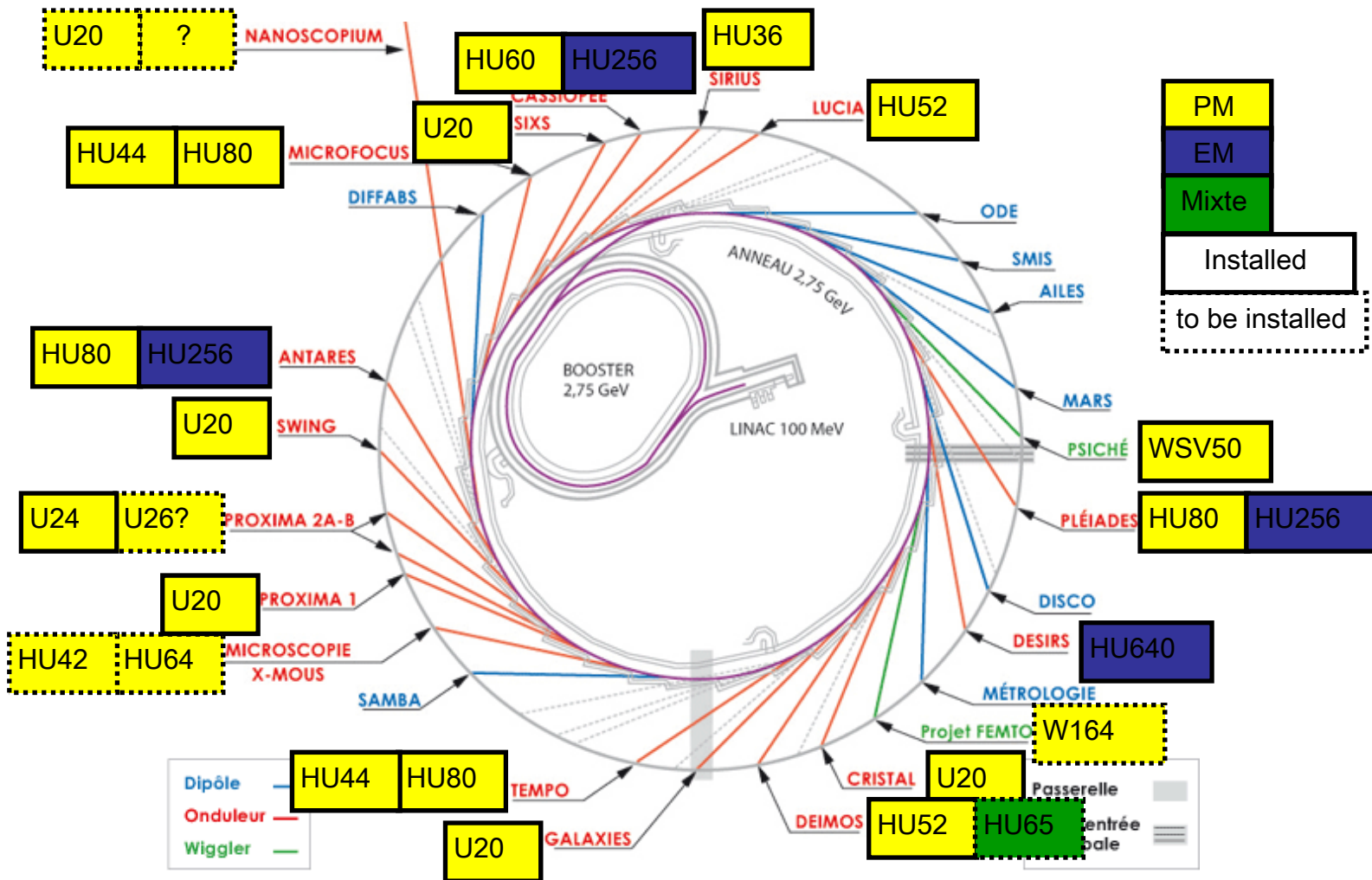
## Room temperature assembly

phase error :  $3.5^\circ$

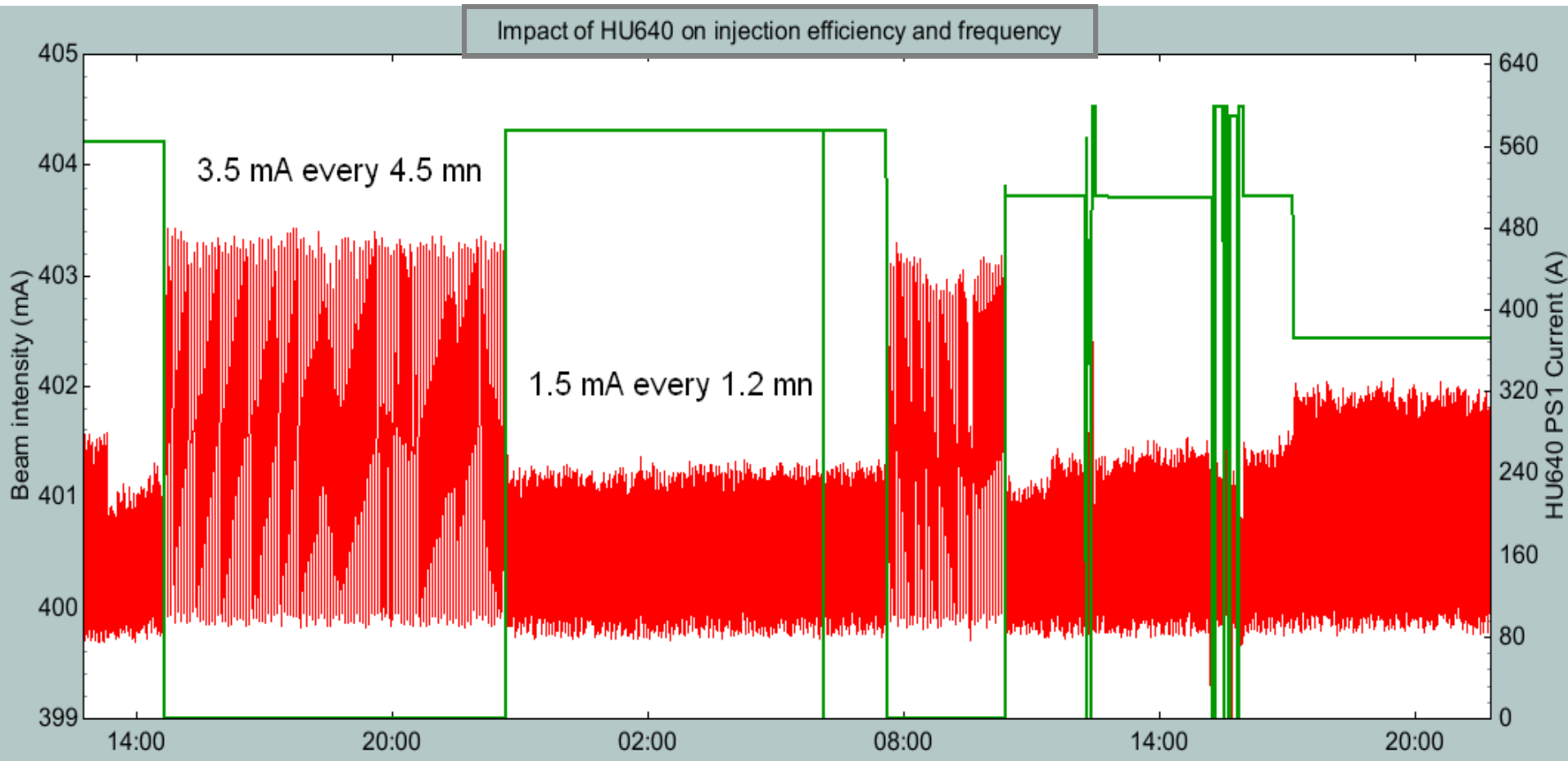




# Implementation of the Insertion Devices

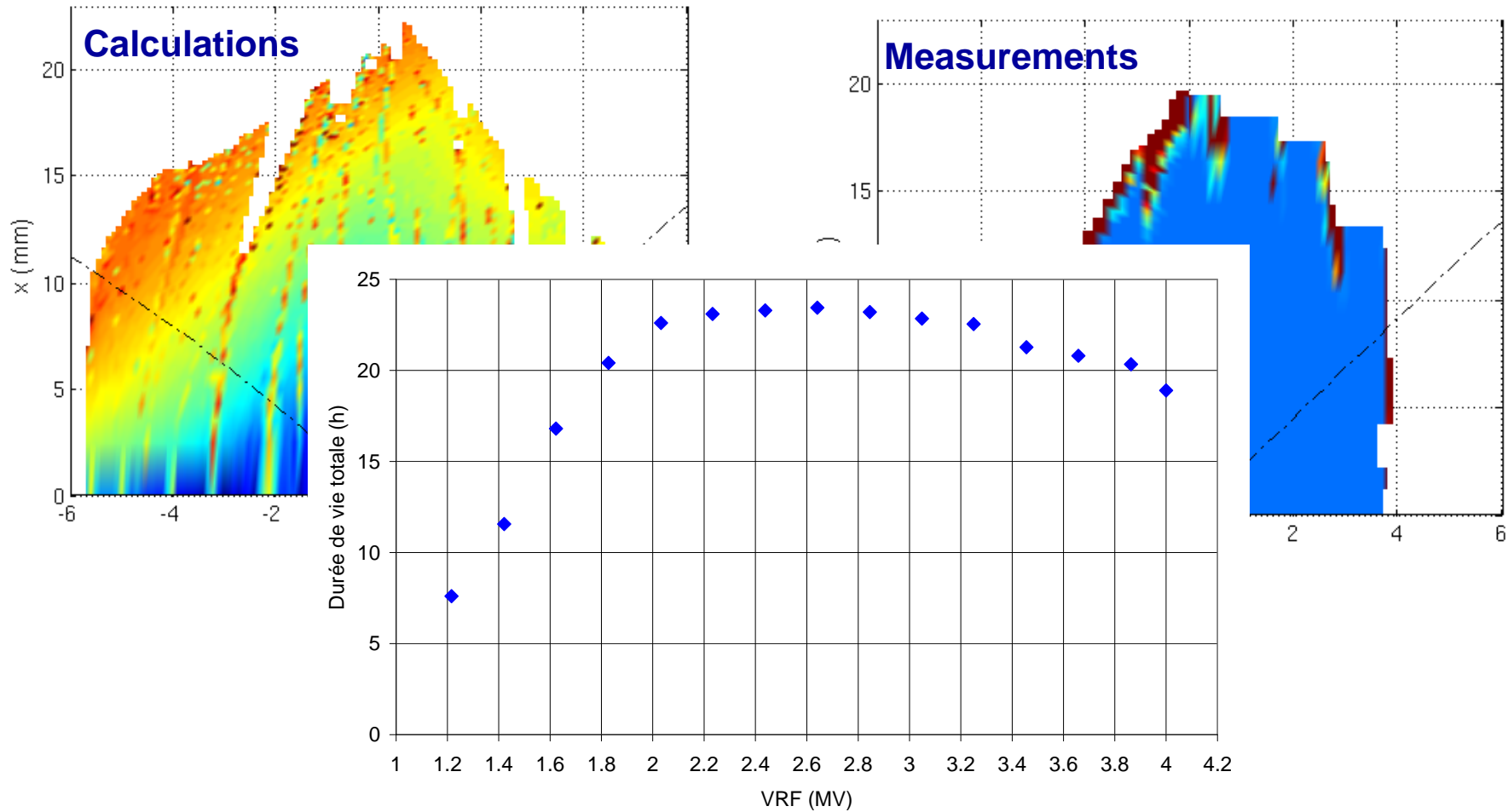






# Energy Acceptance of the Bare Machine

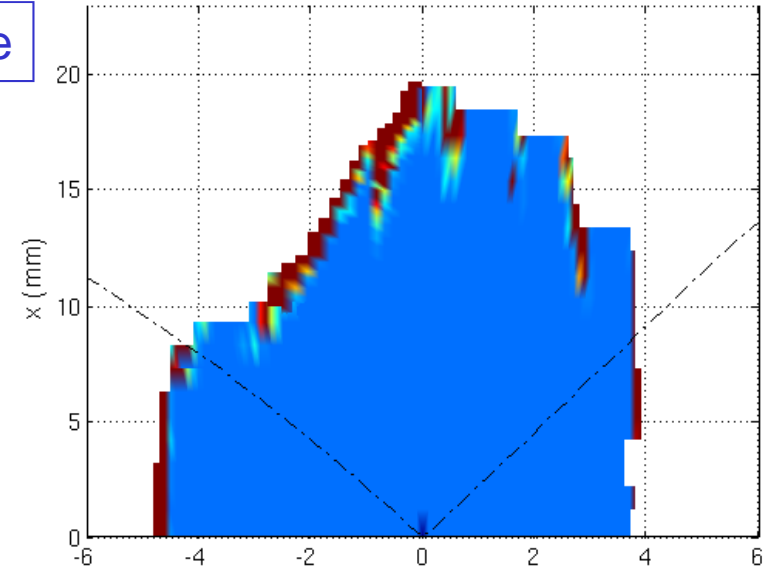
*The energy acceptance of the bare machine is large : +/- 4%.  
Off-momentum FMA experiments have confirmed calculation results*



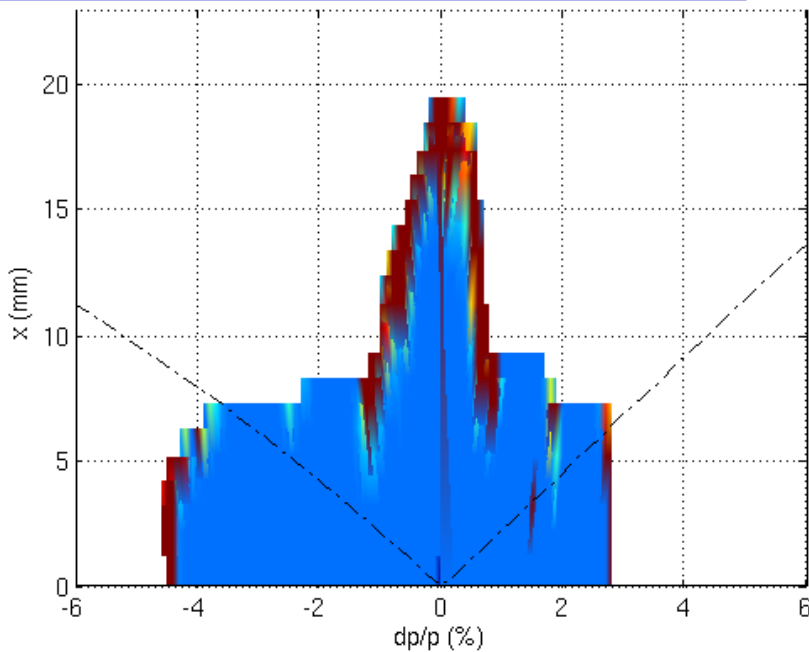
# Effect of the Insertion Devices

Bare machine

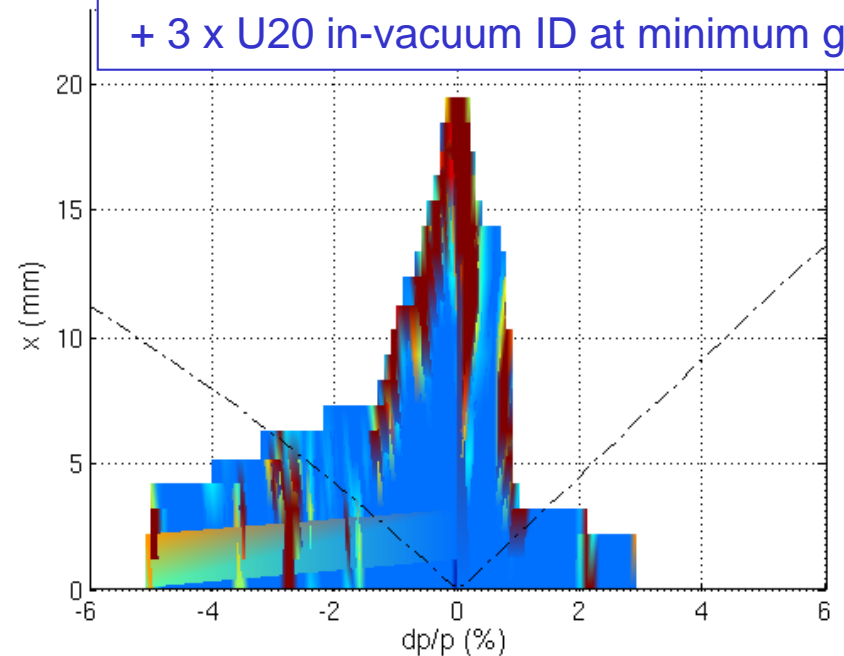
*The measured energy acceptance  
is significantly reduced  
in the presence of IDs*



HU640 ID at maximum field in LV-mode



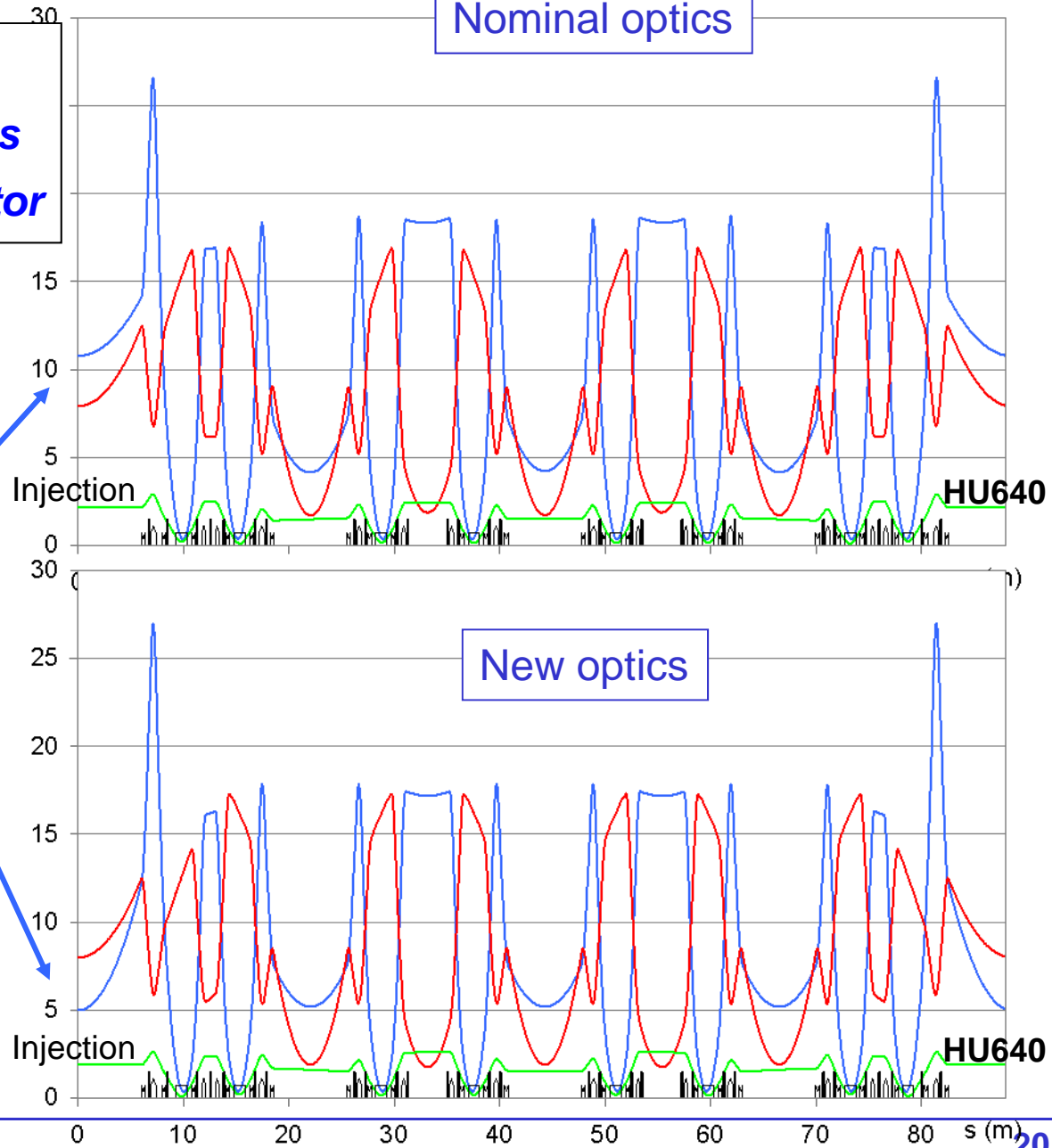
HU640 ID at maximum field in LV-mode  
+ 3 x U20 in-vacuum ID at minimum gap



## A new optics

to reduce the non linear effects  
of the 10m long HU640 undulator

The horizontal  $\beta$ -function  
is reduced from 10 m  
to 5 m



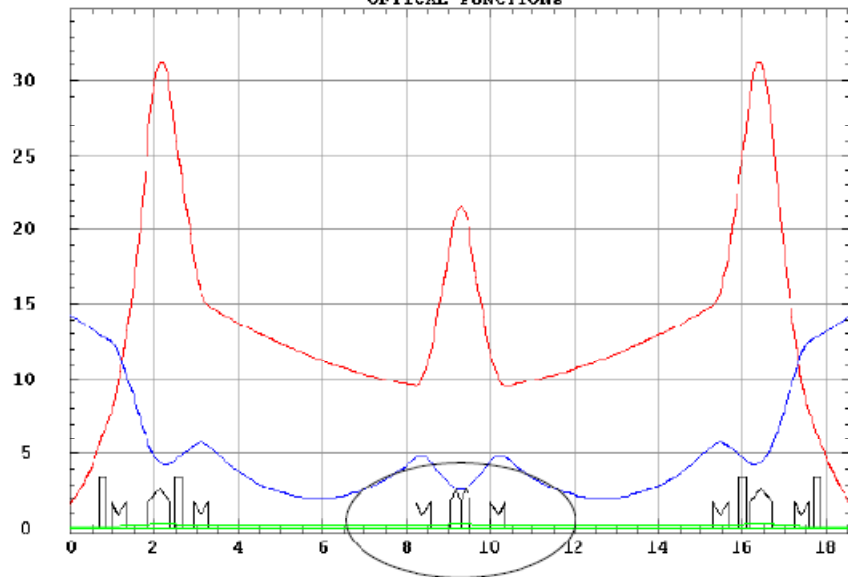
- ❑ *The tunes remain unchanged : 18.2020 – 10.3170*
- ❑ *The nominal horizontal emittance remains unchanged : 3.7 nm.rad*
- ❑ *The injection rate of the bare machine remains unchanged by scaling the kickers by a factor of 1.04*
- ❑ *The beam lifetime is a little bit reduced for the bare machine but is improved in the presence of IDs*

<b>Beam lifetime (h) @ 400 mA (416 bunches)</b>	<b>Nominal Optics</b>	<b>New Optics</b>
<b>Bare machine</b>	<b>20</b>	<b>18</b>
<b>HU640 at maximum field in LV-mode</b>	<b>12</b>	<b>16</b>
<b>HU640 at maximum field in LV-mode + 5 x U20 in-vacuum IDs at minimum gap</b>	<b>7</b>	<b>10</b>

# Double mini- $\beta_z$ Optics

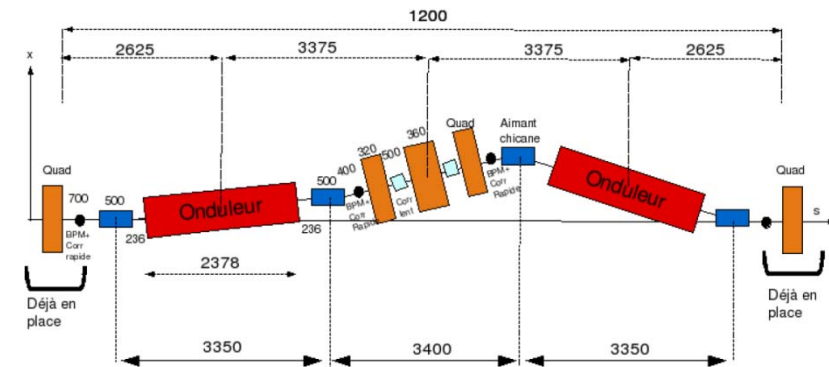
- ❑ Nanoscopium and Tomography :  $\sim 150$  and  $\sim 200$  m long beamlines will exploit high brilliance and coherence characteristics of the X-ray (5-25 keV) photon beam, both for diffraction limited focusing and for phase contrast imaging.
- ❑ Two canted in-vacuum undulators will be accommodated in a 12 m long straight section, with a 6.5 mrad separation angle.
- ❑ To provide low vertical beta functions at each undulator, an extra triplet of quadrupoles is added in the middle of the section.
- ❑ First operation with insertions planned for **Autumn 2011**

BETA-LNS 01.10 / 22/01/08/ 8-Sep-09 18:12:03 Sci 0.000E+00  
OPTICAL FUNCTIONS



Double low beta optics

Extra quadrupoles triplets



In order to test the new machine optics, a triplet of quadrupoles has been installed temporary.

# Experiment with Double mini- $\beta_z$ Optics

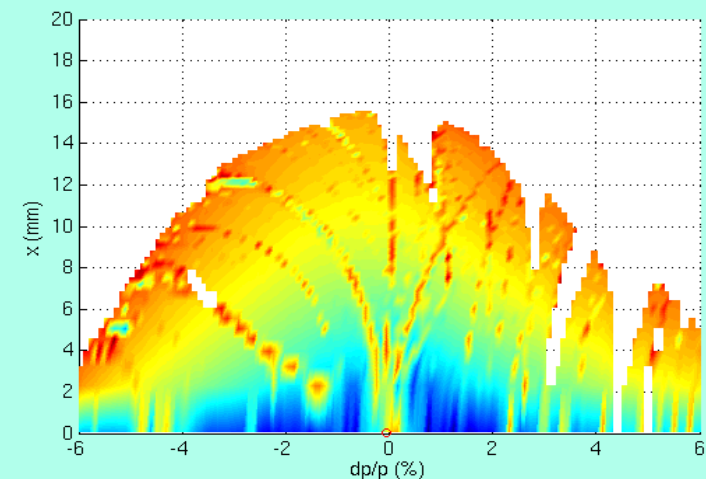
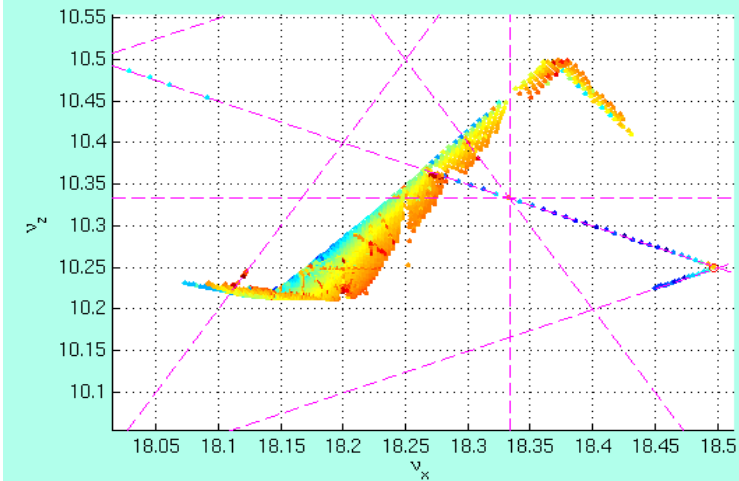
- The 4th symmetry of the machine is broken  $\Rightarrow$  machine symmetry = 1

## Measured Beam Lifetime at 400 mA multibunch mode

Optics	Working Point	Beam lifetime (h) : Bare Machine	Beam lifetime (h) : 5 in-vacuum at mini gap
Present	18.2 - 10.3	20	11
Modified 1 (different sextupole setting)	18.2 - 10.3	6	6
Modified 2 (different sextupole setting)	18.17 - 10.25	20	15

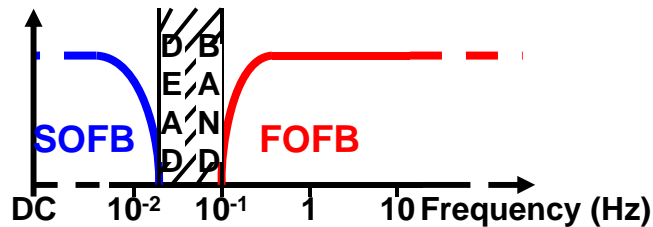
Working Point still under investigation as well as sextupoles tuning, from experience and simulations (BETA & Tracy & OPA codes)

Simulation (Tracy): optics Modified 2



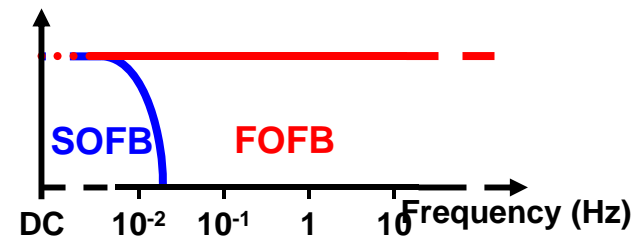
## Up to now with 2 different sets of correctors (Slow and Fast):

- ‘Dead Band’ solution:
  - SOFB and FOFB are efficient on different frequency ranges.
  - No suppression of ID disturbances



## We have combined SOFB and FOFB

- Common frequency range.
  - ID disturbances are well suppressed
- Interaction between SOFB and FOFB:
  - Download of DC part in the fast correctors by the slow ones
  - FOFB reference orbit is updated runtime by SOFB



## With two orbit feedback systems working together, machine stability benefits from:

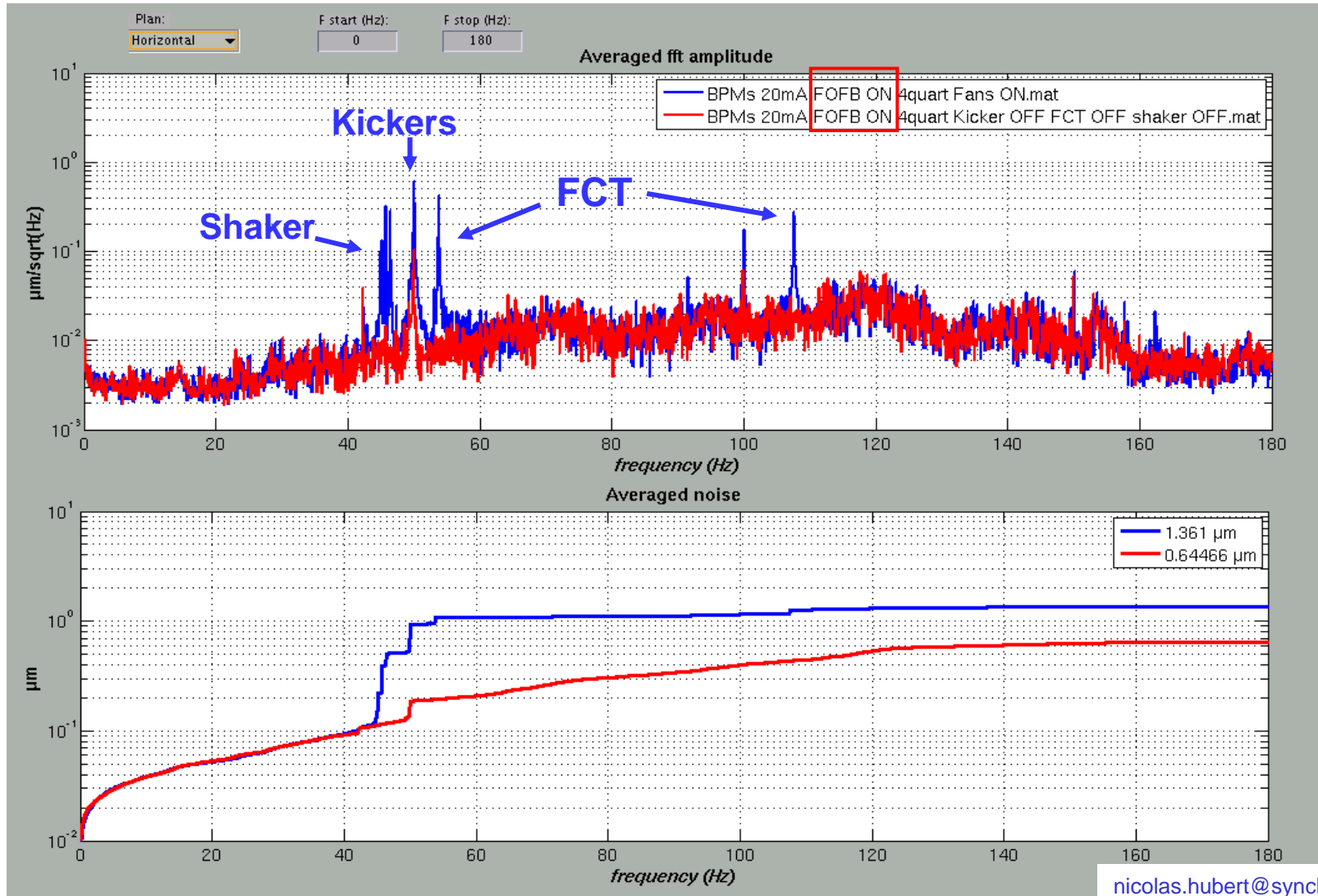
- The slow system that provides good long term stabilization at all source points (also at bending magnets)
- The fast system that suppresses shorter term beam perturbations

## The use of a different set of fast correctors for fast corrections seems to be a good choice for:

- New machines:
  - Requiring high frequency corrections (above 100 Hz)
  - Requiring large kick strength with high resolution
  - With Aluminum vacuum sections at strong corrector locations
- Older machines:
  - That want to upgrade their orbit feedback system at a reasonable cost



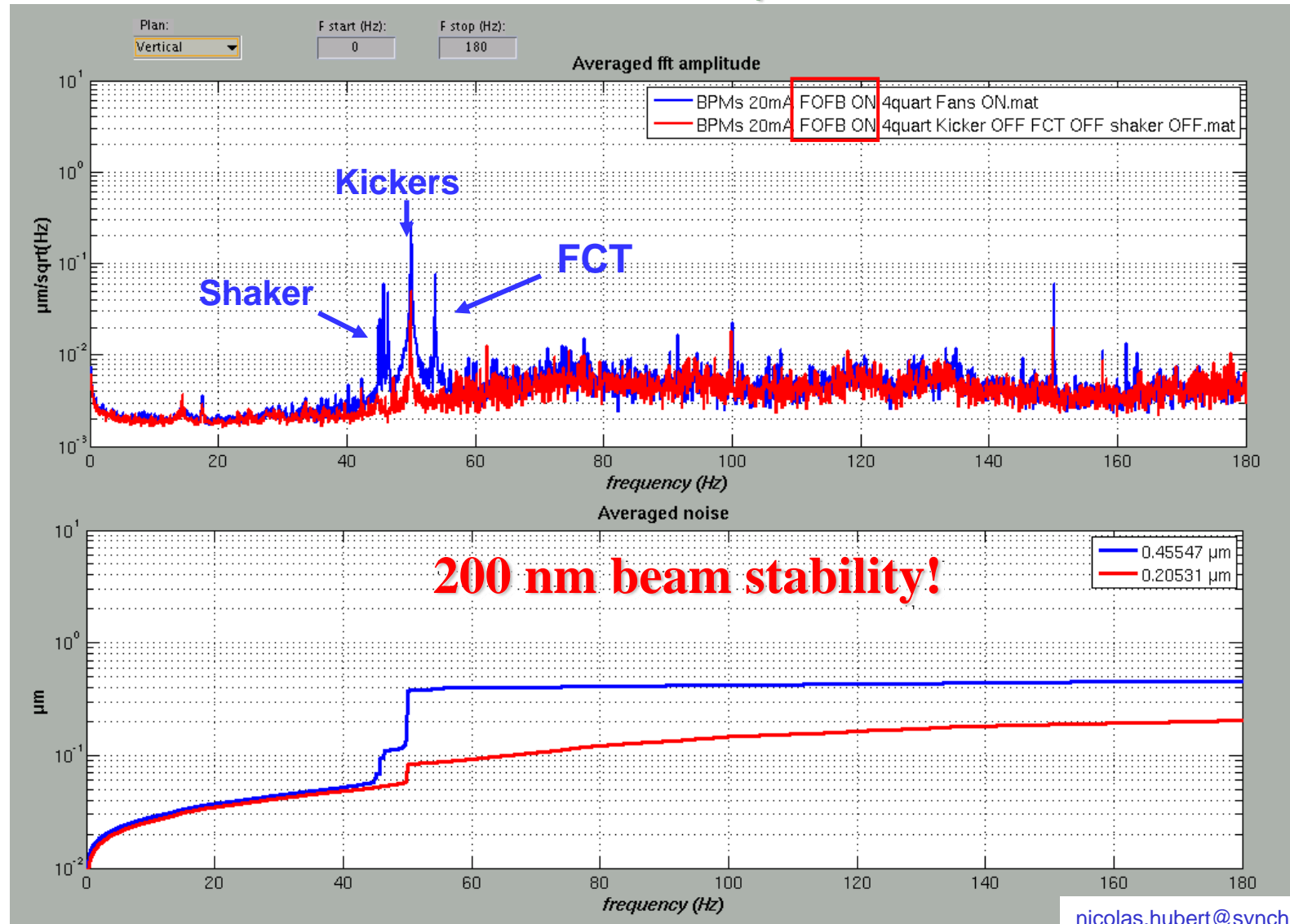
Power Spectral Density (PSD) and integrated PSD averaged on 120 BPMs in the horizontal plane



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# Perturbation by Fans

Power Spectral Density (PSD) and integrated PSD averaged on 120 BPMs in the **vertical plane**:



# Mini-workshop (or brainstorming) on XBPMs

## SOLEIL, November 4th & 6th

### Two main issues prompted the workshop:

1. Dark current growth in one or two years of operation on XBPMs
2. Clear requirements for Instrumentation Technologies Libera photon

### Conclusions:

1. **Dark currents:** Analysis of black deposits shows metallic traces (Al, Fe, Ni, etc...) but the method is blind to carbon. The metals could be vaporised impurities in tungsten blades if high power photon beam accidentally hits a blade. It could also be the same process of carbon formation seen on SOLEIL beamline mirrors. An additional analysis sensitive to carbon will be performed.  
Solution: whatever the cause, the deposition speed must be slowed down with a **chicane-like shield of the insulators.**
2. Libera-Photon requirements. The requirements will be sent to IT by Nov. 30th
3. **Common statement:** Photon BPMs have a very good resolution, even better than electron BPMs. The workshop participants are going to share data in order to prove the XBPMs are reliable and can be used in orbit feedback systems.
4. **Another workshop next year is proposed by SLS.** It will address orbit feedback issues in addition to the XBPM ones.

# 500 mA

Successful test and Radiation control on April 6, 2010

06/04/10

ID

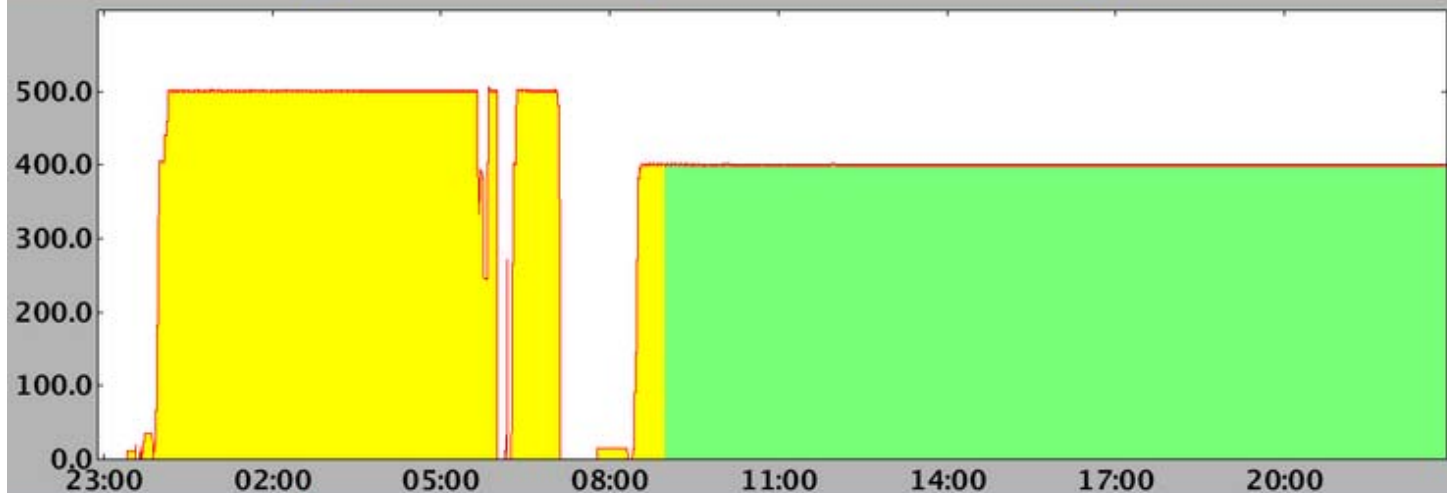
BM

**SOLEIL MACHINE NOW READY FOR 500 mA OPERATION**

Radiation Safety validation of each beamline at 500 mA is going on

12 Beamlines already validated for 500 mA operation

1.0e-09 mbar	H	48.0 $\mu\text{m}$	293.3 $\mu\text{m}$	3.97 nm.rad	0.2008
End Of Beam	V	67.3 $\mu\text{m}$	374.0 $\mu\text{m}$	51.9 pm.rad	0.3161
Apr-12 07:00:00	Delivery Since				
128:06:33	Tue Apr 6 09:00:00		Shift Lignes		

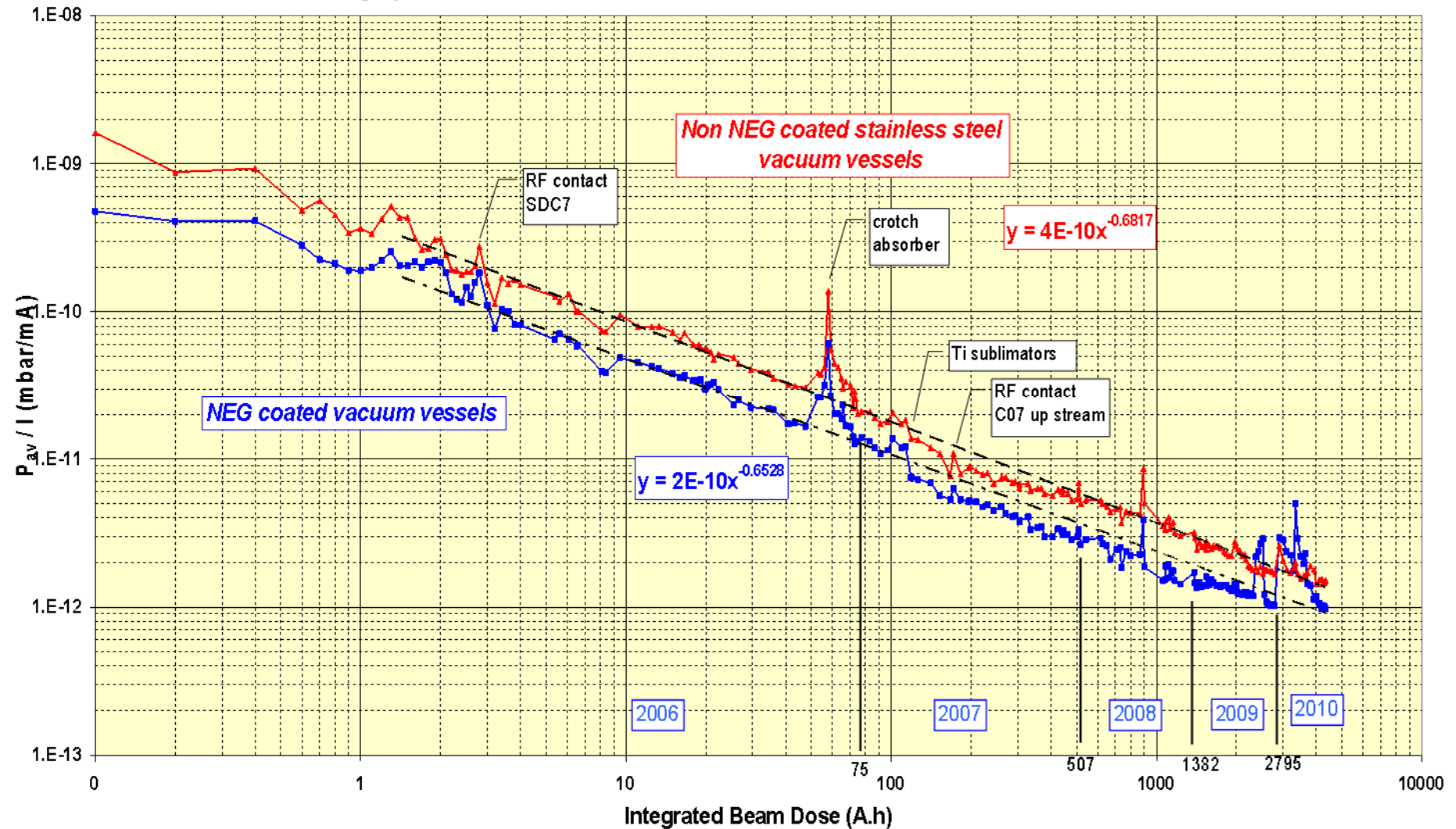


Tue Apr 6 09:00:29

Faisceau disponible

# Vacuum Chambers Conditioning

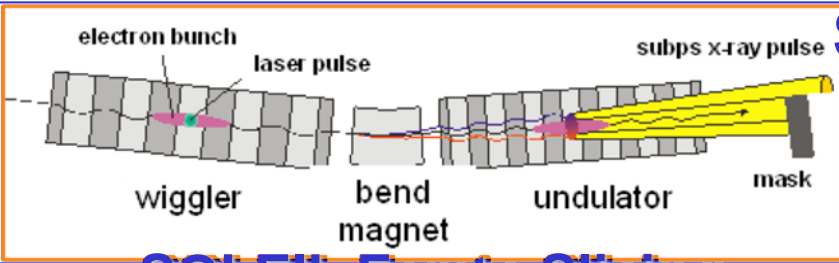
Average pressure of Cell C07 normalised to current Vs. the beam dose



**Goal for a pressure  $< 10^{-9}$  mbar at 500 mA has been achieved !**



## Principle



SOLEIL scheme: under construction

## SOLEIL Femto Slicing

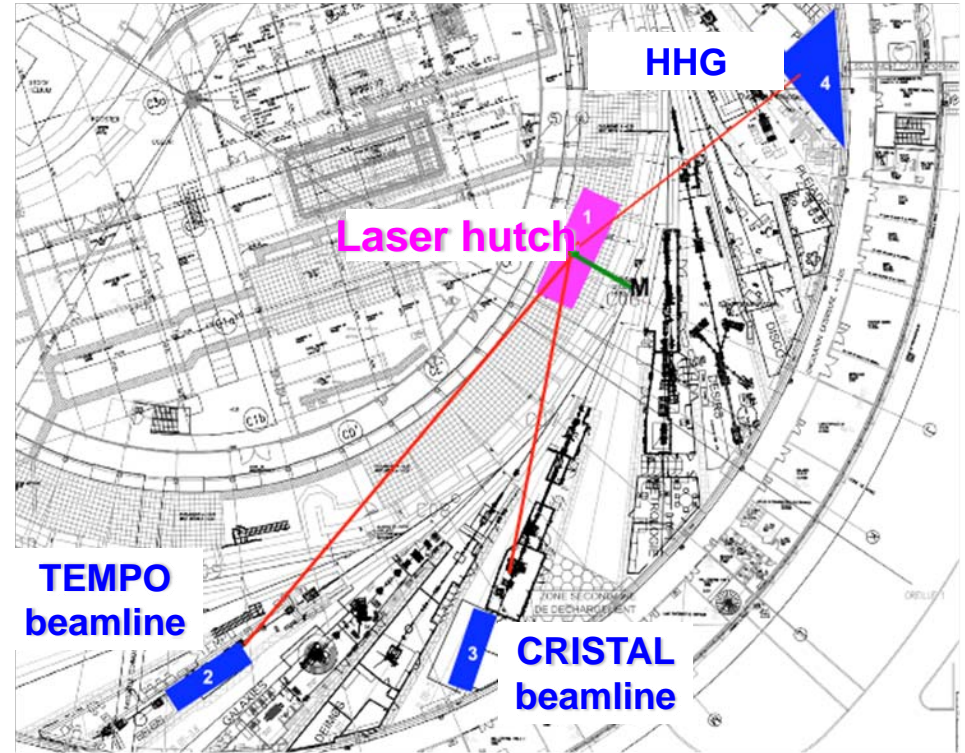
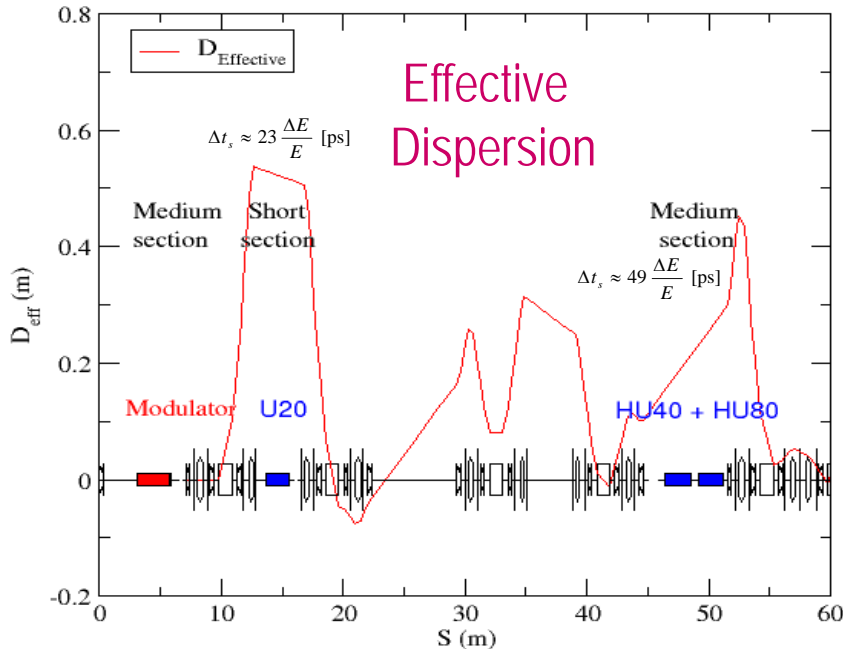
### parameters

Laser system : 800 nm, 10 kHz, 30 fs, 5 mJ

Wiggler : period 164 mm, 3 m length, first harmonic at 800 nm

Slicing provided on 2 beamlines

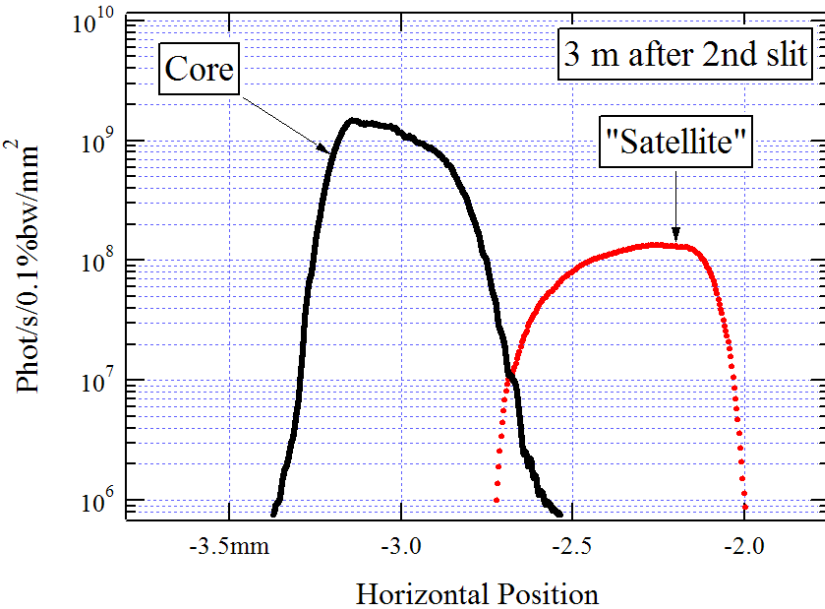
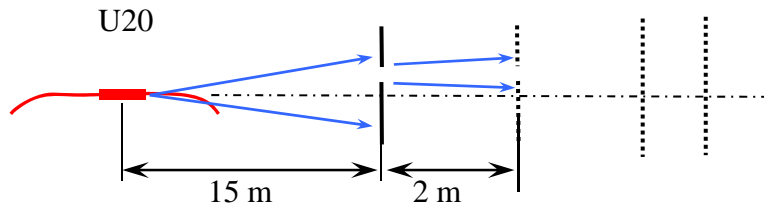
Transverse separation via the natural dispersion



A minimum of 2 beamlines can profit from the process with high efficiency separation (2012)

## CRISTAL

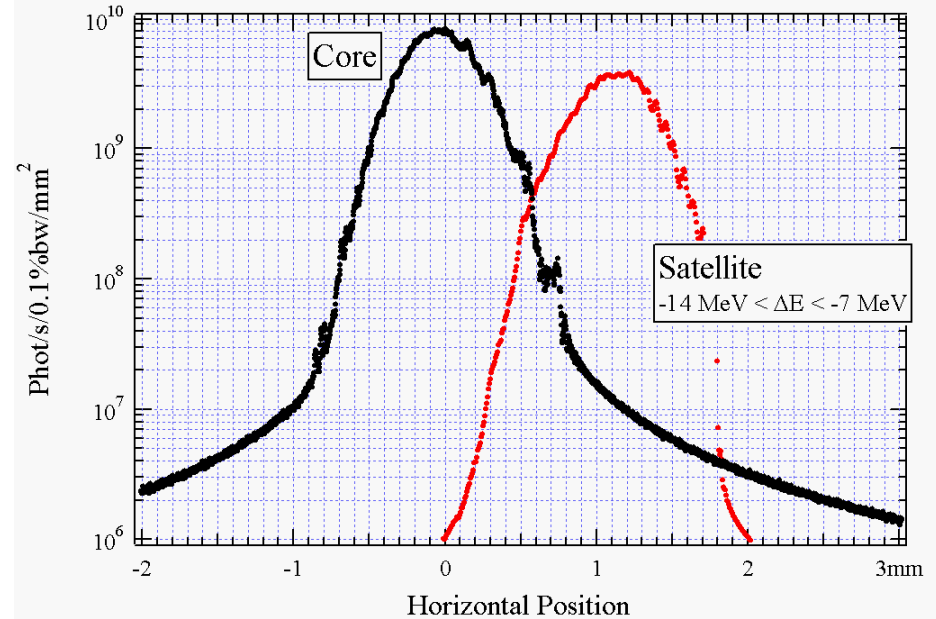
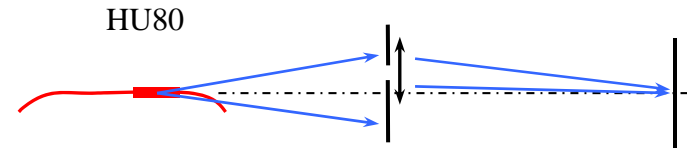
Slit (Pinhole)



## TEMPO

Slit +  
Mirror

Plane of 1:1  
Imaging

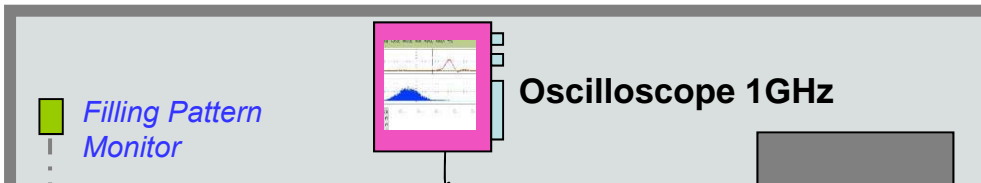


Durée totale de l'impulsion (FWHM en fs).

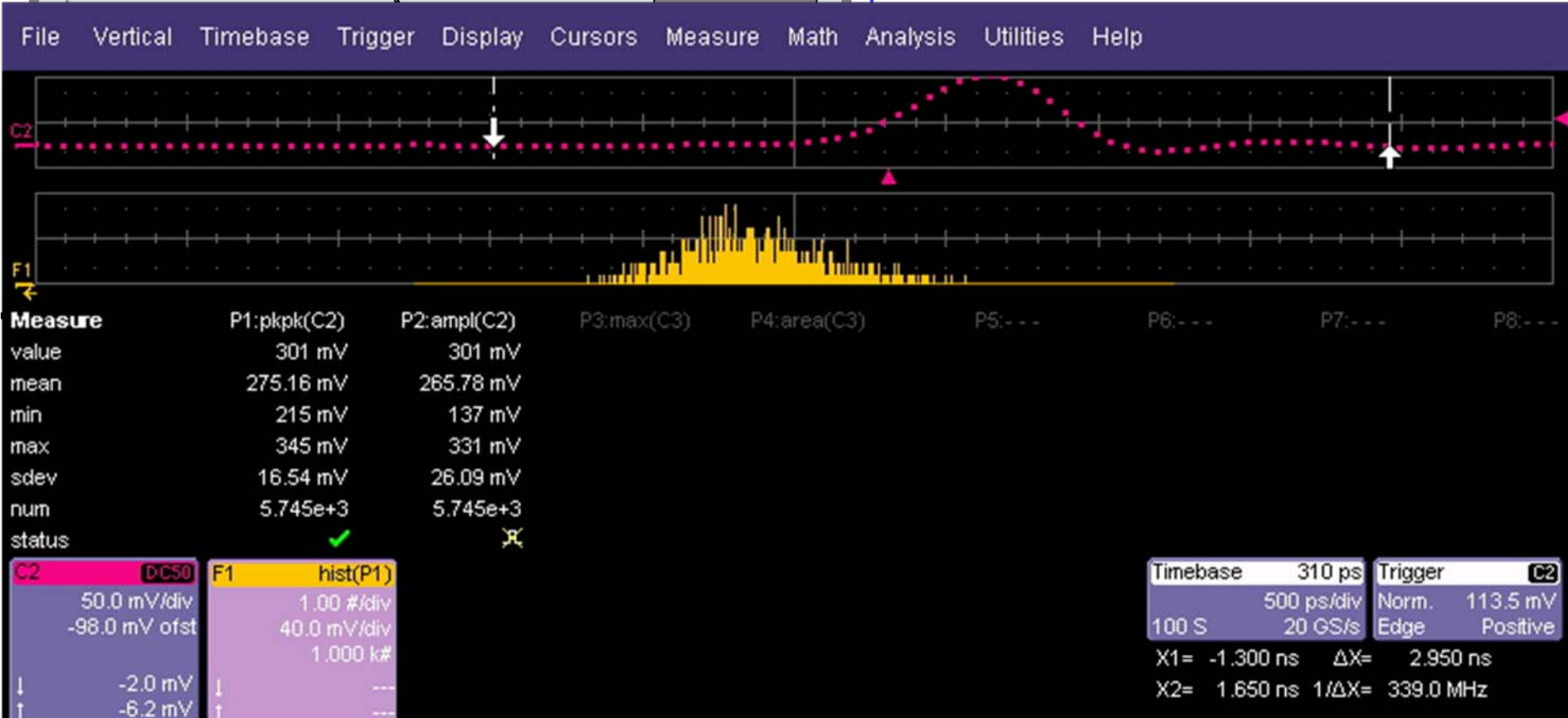
Radiateur	Laser	Slippage	Emittance	Dispersion en énergie	Total
CRISTAL	50	53	54	52	104
TEMPO	50	53	47	117	145

## using the Incoherent Radiation Fluctuation

Visible light diagnostic hutch



Simple bunch length measurements can be achieved at low cost. The shorter





**6<sup>th</sup> generation transistors ( $V_{dc} = 50$  V) + SOLEIL expertise → fast progress**

**→  $P_{mod} \sim 700$  W,  $G > 20$  dB,  $\eta > 70\%$  @ 352 MHz**

**[ Current module ( $V_{dc} = 28$  V) :  $P = 315$  W,  $G = 13$  dB,  $\eta = 62\%$  @ 352 MHz ]**

**→ Huge improvement :  $P_{mod} \times 2.2$  , better performance ( $G > 20$  dB,  $\eta > 70\%$ )**

**& thermal stress strongly reduced ( $T_{max} : 130$  °C →  $\sim 70$  °C) → longer lifetime**

**→ Similar performance @ 500 MHz**

**→ Beg. 2009, transfer of technology agreement concluded with ELTA-AREVA**

**→ ESRF contract for 7 SOLEIL type amplifiers of 150 kW (14 x 75 kW towers)**

## Collaboration agreements

- LNLS (Brazilian LS) : 2 x 45 kW @ 476 MHz under commissioning
- SESAME (LS in Jordan) : 4 x 150 kW @ 500 MHz

## R&D at other frequencies

- FM band (88 – 108 MHz) → 1 kW module with  $G > 25$  dB and  $\eta \sim 80\%$
- L band (1.3 & 1.5 GHz) for 4<sup>th</sup> generation LS →  $P_{mod} > 400$  W
- Applicable to any frequency from FM to L Band