Version 2.0

SOLEIL SYNCHROTRON

Progress Report on Synchrotron SOLEIL

Laurent S. Nadolski

On behalf of the Accelerator and Source Division

Contents

- Beamlines
- Operation
- Top-up operation
- Towards 500 mA
- Orbit stability
- Insertion devices and RF systems

20 BLs: 12 ID based, 6 Dipole based, 2 IRs
26 BLs funded (max number: 38 BLs)

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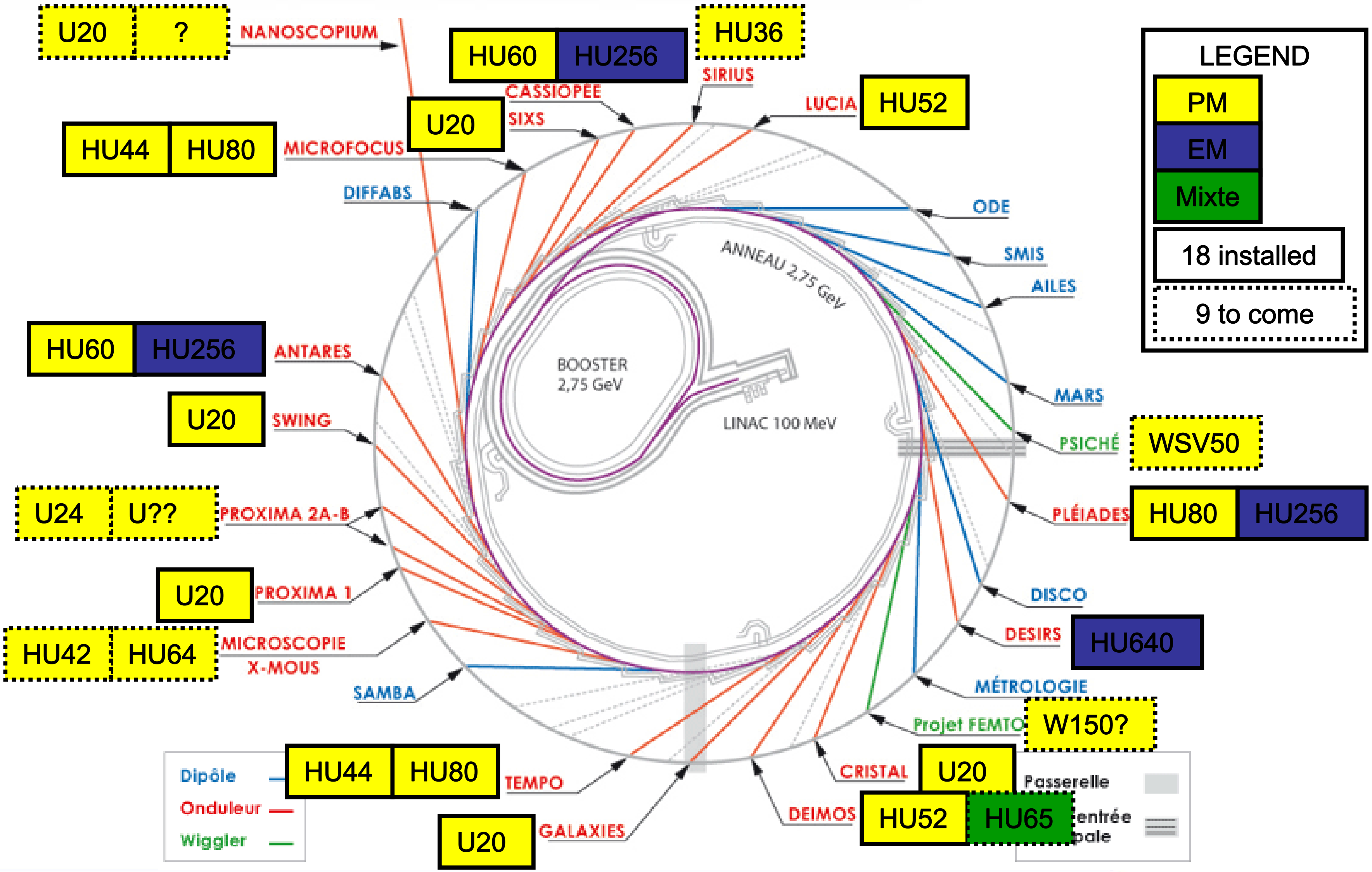
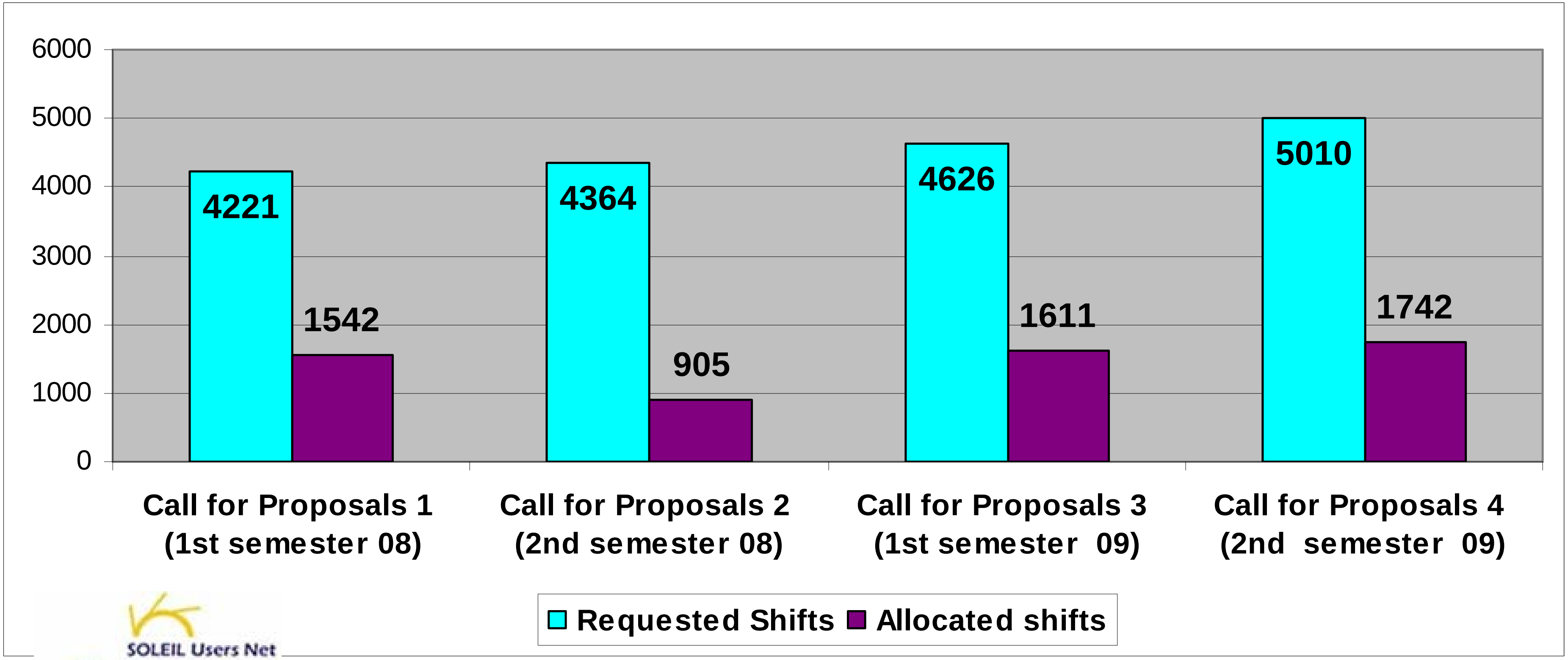


Beam-time requests and allocation since the beginning of operation of SOLEIL

All phase 1 beam-lines are now welcoming external users. The pressure is high on all beamlines (2.9 on average for 4th call for proposals, 29% of the applications from outside France).



SOLEIL Users Net SUN set

Bureau des Utilisateurs-F. Fraissard, juin 2009

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User beam conditions

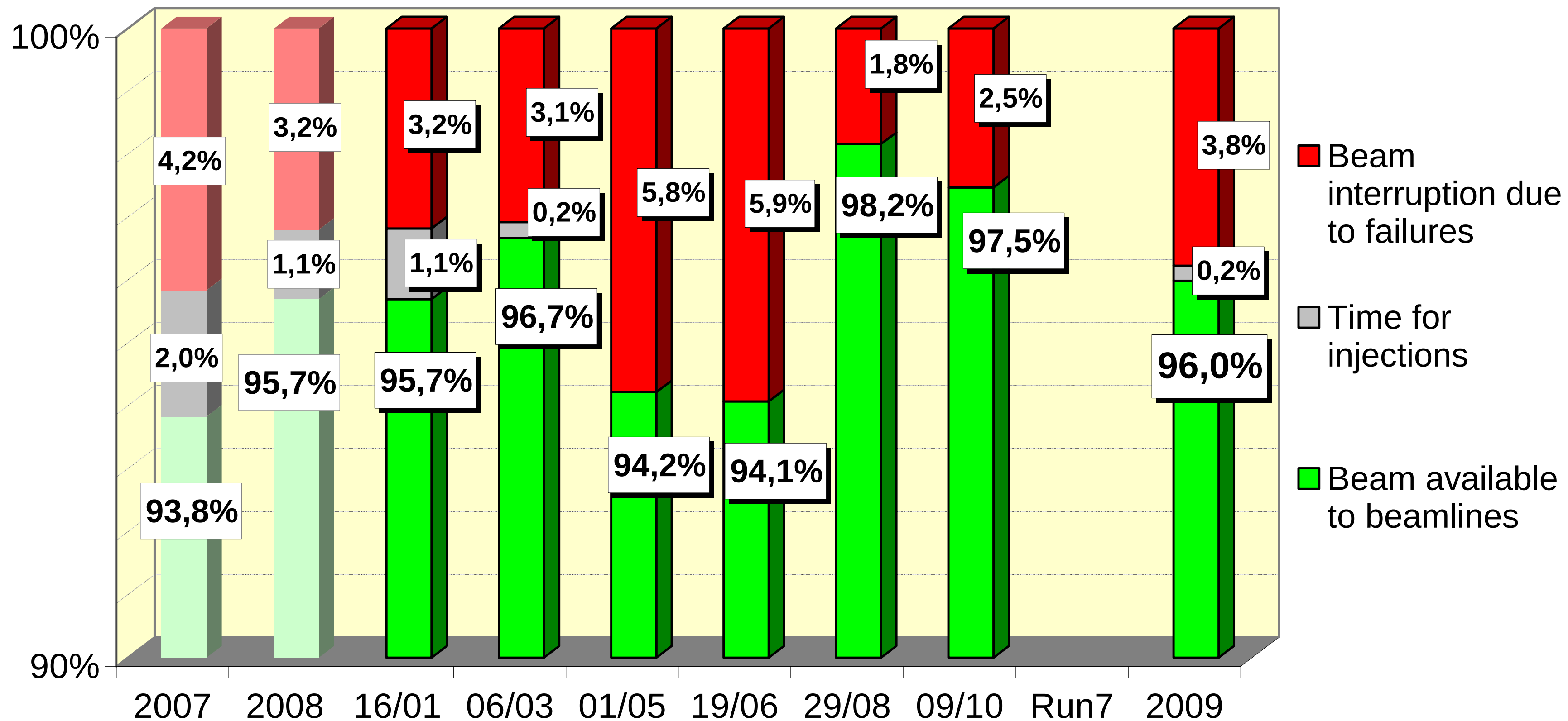
Jan-Nov. 2009

- **Top-up mode since March 2009**
- **With various filling patterns (Beam lifetime depends on ID config.)**
  - 20.5% : High flux mode all bunches (400/416) filled, 250 mA, τ = 14-24 h, 1% coupling
  - 72% : High flux mode all bunches (400) filled, 300 mA, τ = 14-18 h, 1% coupling
  - 3.5% : Hybrid mode (300 + 1 single @ 8 mA), 300 mA, τ = 14-18 h, 1% coupling
  - 3.5%: 8 bunch mode (total current of 60 mA), τ = 3.5-4 h, 1% coupling
  - 0.5%: 1 bunch, 10 mA, τ = 4.5h, 1% coupling
- **Feedback and feedforward loops**
  - Slow Orbit Feedback loop
  - Fast Orbit Feedback loop (new: SOFB+FOFB since April 2009)
  - Fast Transverse Feedback loop (improvement)
  - Tune feedback loop (new)
  - Insertion device feedforward loops for closed orbit

Machine operation

Availability of the beam :

93.8% in 2007 (2 640 hours delivered)
95.7% in 2008 (3 882 hours del. over 4 056 h scheduled)
96.0% in 2009 (3 967 hours del. as of November 15th)



Mean Time between Failures was **32 hours in 2008**.
The average duration of failure was 31 minutes.

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Operation planning in 2009

janv 2009		févr 2009		mars 2009		avr 2009		mai 2009		juin 2009		juil 2009		août 2009		sept 2009		oct 2009		nov 2009		déc 2009	
jeu 01	. . .	dim 01	N N N	dim 01	. . .	mer 01	T T T	ven 01	m m m	lun 01	. . .	mer 01	8 8 8	sam 01	. . .	mar 01	p l l	jeu 01	. . .	dim 01	l l l	mar 01	l l l
ven 02	. . .	lun 02	m m m	lun 02	. . .	jeu 02	T T T	sam 02	m m m	mar 02	. . .	jeu 02	8 8 8	dim 02	. . .	mer 02	l l l	ven 02	. . .	lun 02	m m m	mer 02	l l l
sam 03	. . .	mar 03	N N r	mar 03	. . .	ven 03	T T T	dim 03	m m m	mer 03	. . .	ven 03	8 8 8	lun 03	. . .	jeu 03	l l l	sam 03	. . .	mar 03	l l l	jeu 03	l l l
dim 04	. . .	mer 04	N N N	mer 04	. . .															mer 04	l l l	ven 04	l l l
lun 05	. . .	jeu 05	N N N	jeu 05	. . .															jeu 05	l l l	sam 05	l l l
mar 06	. . .	ven 06	N N N	ven 06	m m m															ven 06	l l l	dim 06	l l l
mer 07	. . .	sam 07	N N N	sam 07	m m m															sam 07	l l l	lun 07	m m m
jeu 08	. . .	dim 08	m m m	dim 08	m m m															dim 08	l l l	mar 08	l l l
ven 09	. . .	lun 09	m m m	lun 09	m m m															lun 09	. . .	mer 09	l l l
sam 10	. . .	mar 10	N N r	mar 10	N N r															mar 10	. . .	jeu 10	l l l
dim 11	. . .	mer 11	N N N	mer 11	N N N															mer 11	. . .	ven 11	l l l
lun 12	. . .	jeu 12	N N N	jeu 12	N N N															jeu 12	. . .	sam 12	l l l
mar 13	. . .	ven 13	N N N	ven 13	N N N															ven 13	. . .	dim 13	l l l
mer 14	. . .	sam 14	N N N	sam 14	N N N															sam 14	. . .	lun 14	m m m
jeu 15	. . .	dim 15	N N N	dim 15	m m m															dim 15	. . .	mar 15	l l l
ven 16	m m m	lun 16	m m m	lun 16	m m m															lun 16	. . .	mer 16	l l l
sam 17	m m m	mar 17	N N r	mar 17	p T T															mar 17	. . .	jeu 17	l l l
dim 18	m m m	mer 18	N N N	mer 18	T T T															mer 18	. . .	ven 18	l l l
lun 19	m m m	jeu 19	N N N	jeu 19	T T T															jeu 19	. . .	sam 19	l l l
mar 20	N N r	ven 20	N N N	ven 20	T T T															ven 20	m m m	dim 20	l l l
mer 21	N N N	sam 21	N N N	sam 21	T T T															sam 21	m m m	lun 21	l l l
jeu 22	N N N	dim 22	N N N	dim 22	T T T															dim 22	m m m	mar 22	l l l
ven 23	N N N	lun 23	. . .	lun 23	m m m															lun 23	m m m	mer 23	. . .
sam 24	N N N	mar 24	. . .	mar 24	T T r															mar 24	l l r	jeu 24	. . .
dim 25	m m m	mer 25	. . .	mer 25	T T T	sam 25	. . .	lun 25	m m m	jeu 25	H H H	sam 25	T T T	mar 25	. . .	ven 25	l l l	dim 25	l l l	mer 25	l l l	ven 25	. . .
lun 26	m m m	jeu 26	. . .	jeu 26	T T T	dim 26	. . .	mar 26	T T r	ven 26	H H H	dim 26	T T T	mer 26	. . .	sam 26	l l l	lun 26	m m m	jeu 26	l l l	sam 26	. . .
mar 27	p N N	ven 27	. . .	ven 27	T T T	lun 27	. . .	mer 27	T T T	sam 27	H H H	lun 27	T T T	jeu 27	. . .	dim 27	l l l	mar 27	l l l	ven 27	l l l	dim 27	. . .
mer 28	N N N	sam 28	. . .	sam 28	T T T	mar 28	. . .	jeu 28	T T T	dim 28	H H H	mar 28	T T T	ven 28	m m m	lun 28	. . .	mer 28	l l l	sam 28	l l l	lun 28	. . .
jeu 29	N N N			dim 29	m m m	mer 29	. . .	ven 29	T T T	lun 29	m m m	mer 29	T T T	sam 29	m m m	mar 29	. . .	jeu 29	l l l	dim 29	l l l	mar 29	. . .
ven 30	N N N			lun 30	m m m	jeu 30	. . .	sam 30	T T T	mar 30	8 8 r	jeu 30	T T T	dim 30	m m m	mer 30	. . .	ven 30	l l l	lun 30	m m m	mer 30	. . .
sam 31	N N N			mar 31	T T r			dim 31	T T T			ven 31	. . .	lun 31	m m m			sam 31	l l l			jeu 31	. . .

4 416 hours for beam-lines

\+ 168 hours for radiation safety measurements

+1 440 hours for machine shifts

= 36 weeks of electron beam

Progression foreseen for users: **4900 h in 2010**, **5200 h in 2011**, and **5500 h in 2012**

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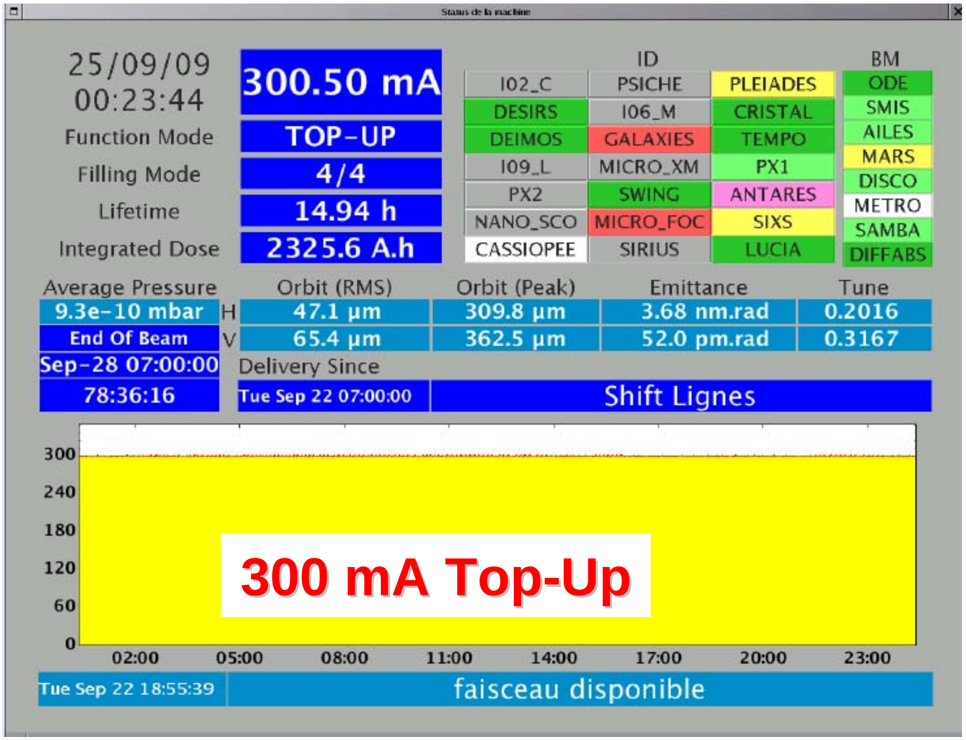
Top-up injection since March 2009



User demand: **ΔI/I < 1%**

Injection every 5 to 8 min

Injection by ¼ of ring (100 bunches)

- Sending injected electrons through the open shutter would only be possible for very high energy: ~ 5 times the nominal energy of the ring

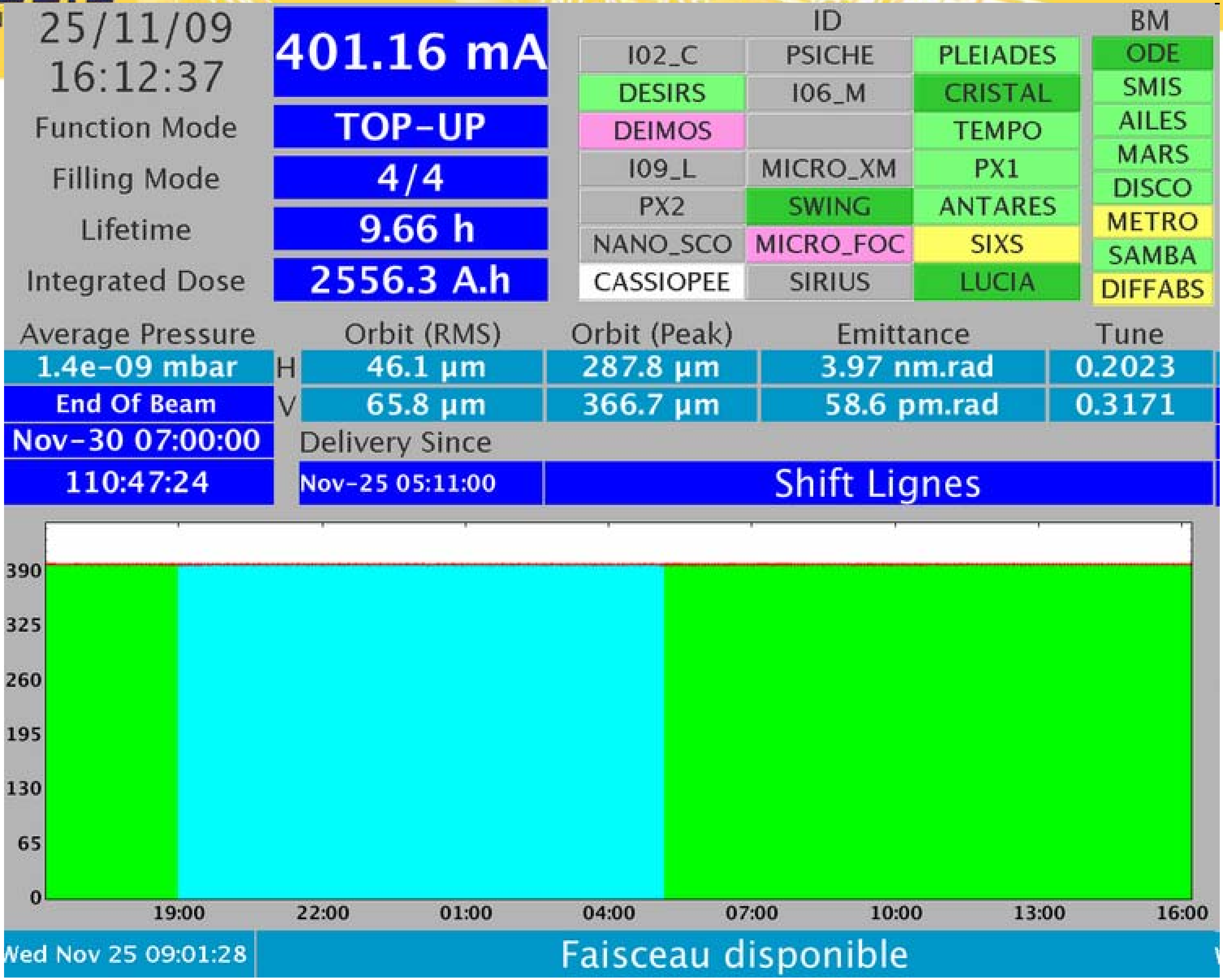
→ Top-up: injection interlocked on 2% mismatch between transfer line and ring dipole power supplies *(hard wired)*

- Safe injection is insured if there is already a stored beam

→ Top-up: injection interlocked on a minimum stored beam current *(hard wired)*

- Shutter closed if accumulated dose exceed 0.8µSv in less than 4 hours on radiation monitors installed along side wall of each beam-line optics hutch *(It never happens so far)*

400 mA top-up since November, 24th 2009



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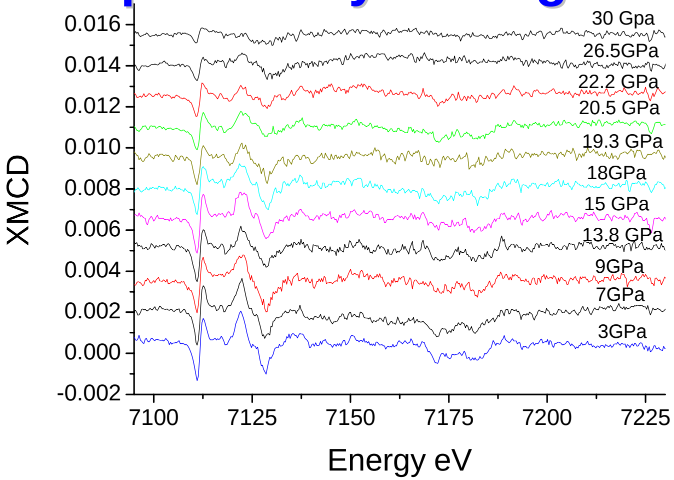
Top-Up and users:

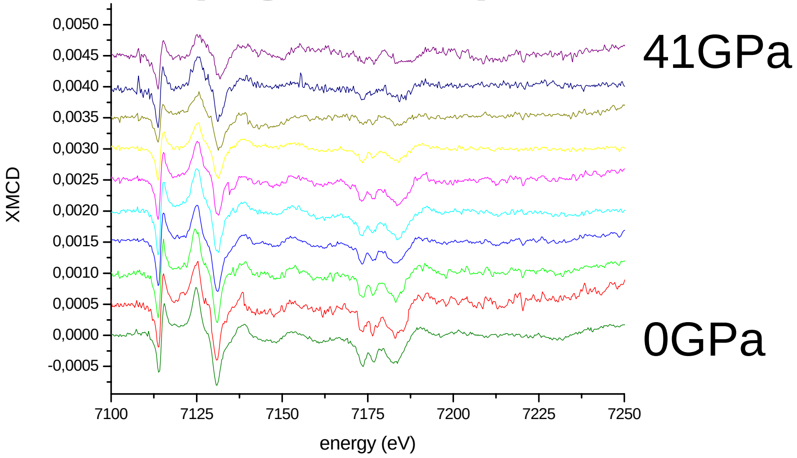
Excellent feedback from beam-lines (IR BLs included)

- ✓ Gain in photon flux (ex. ~30%, DESIRS BL)
- ✓ Better thermal stability for optics and monochromators
- ✓ No more beam current normalization
- ✓ Better stability → better resolution

Example: Study of magnetite under pressure (Ligne ODE)

Data F. Baudelet





July 2008: 250mA ⇒150mA
Slow orbit feedback system
Signal ≈ 10^{-3}
Signal disappears ≈ 30 GPa

March 2009: 300 mA running top-up
Fast Orbit feedback

Signal ≈ 10^{-4} (resolution enough up to 40 GPa), Noise ≈ few 10^{-5}

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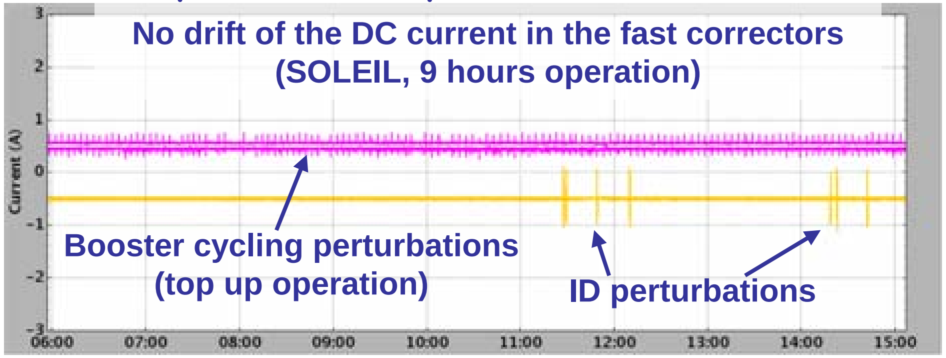
Correction Down to DC

FOFB/SOFB interaction since April 2009

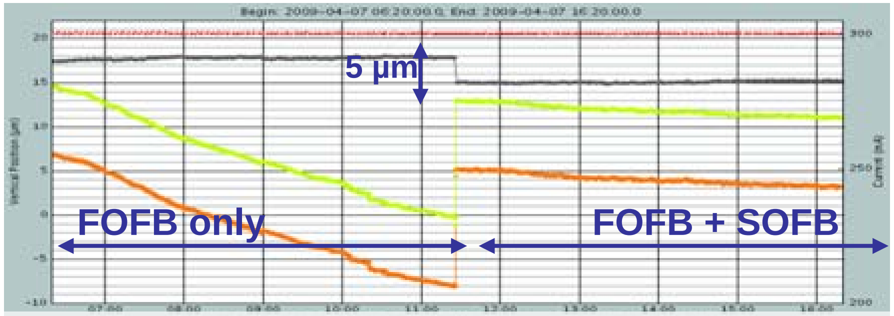
- FOFB and SOFB work together in a very stable way:

No visible orbit drift on the current in the corrector magnets over one week of operation



- Cumulates the benefits of both the feedback systems:

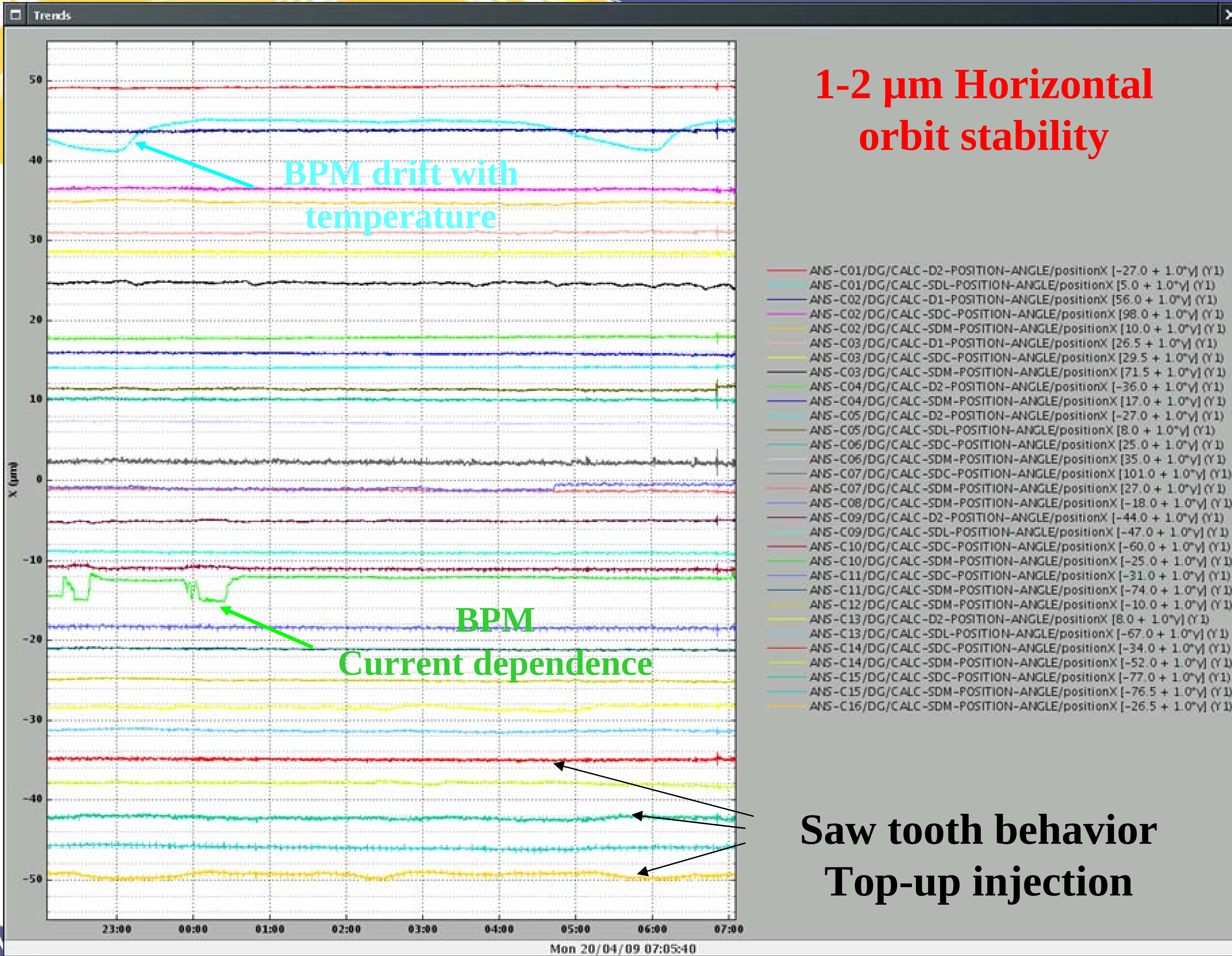
Orbit is well stabilized **even far from fast correctors in the arcs**



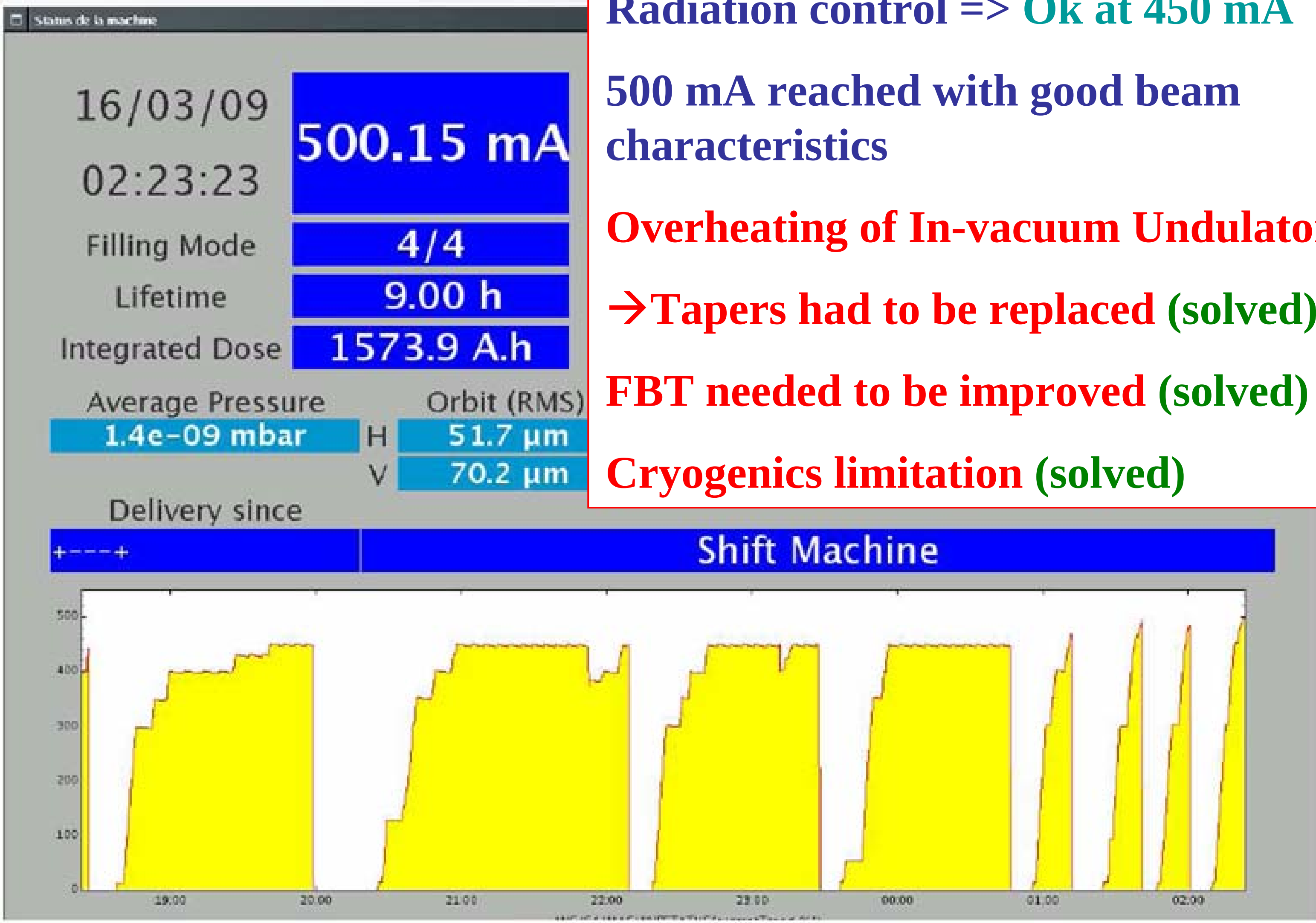
Vertical beam position at one SOLEIL bending magnet source point (BPMs: grey and X-BPMs: orange and green)

- The interaction (slow correction, unload process and change of FOFB reference) does not generate visible parasitic orbit steps. The transient have small enough amplitude and are removed after very few FOFB iteration (10 kHz)

1-2 µm Horizontal orbit stability



Steps towards higher current



Radiation control => Ok at 450 mA

500 mA reached with good beam characteristics

Overheating of In-vacuum Undulators

→Tapers had to be replaced (solved)

FBT needed to be improved (solved)

Cryogenics limitation (solved)

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In-vacuum undulator: New taper design successfully tested

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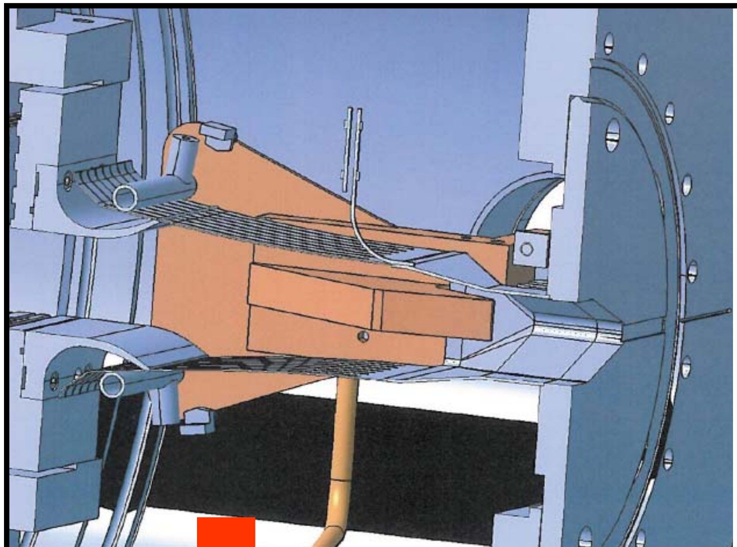
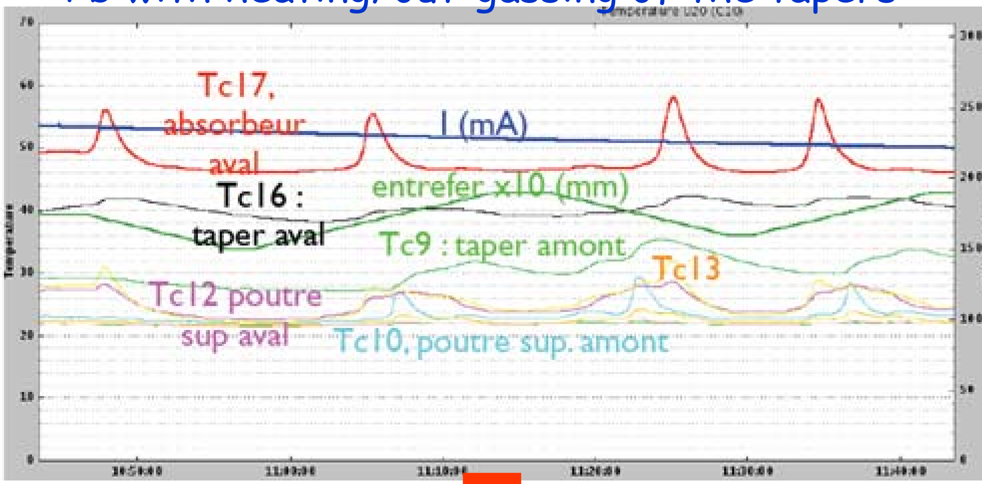
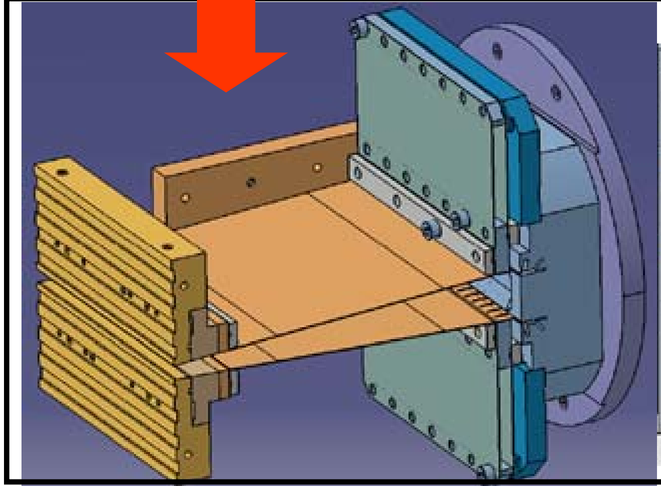
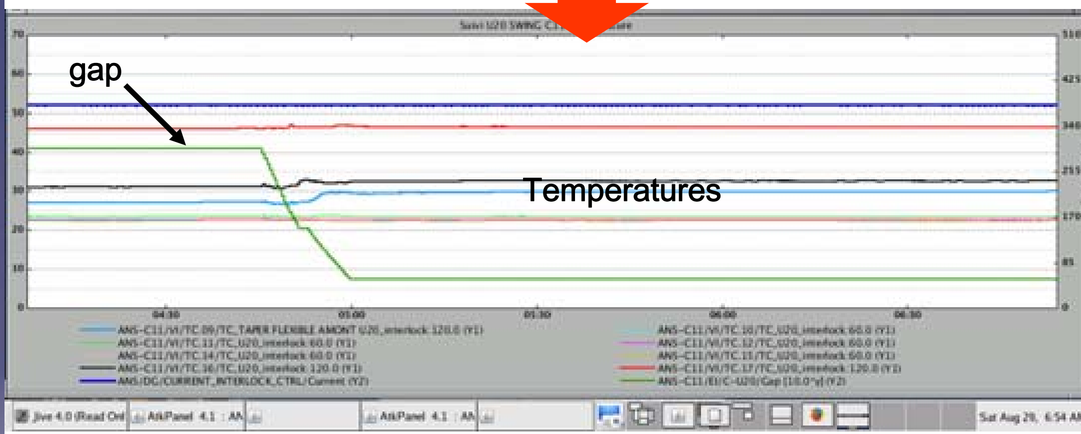
Pb with heating/out-gassing of the tapers





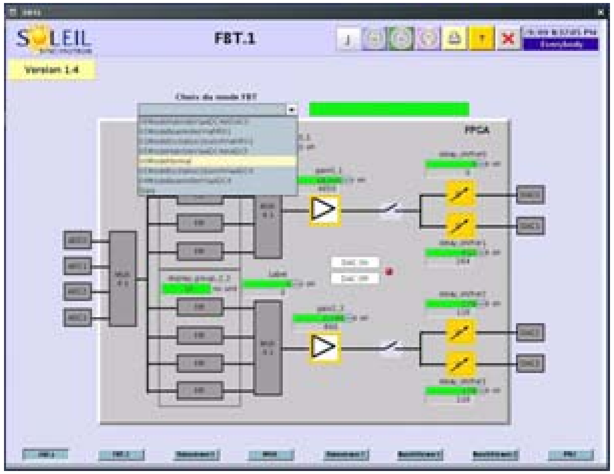




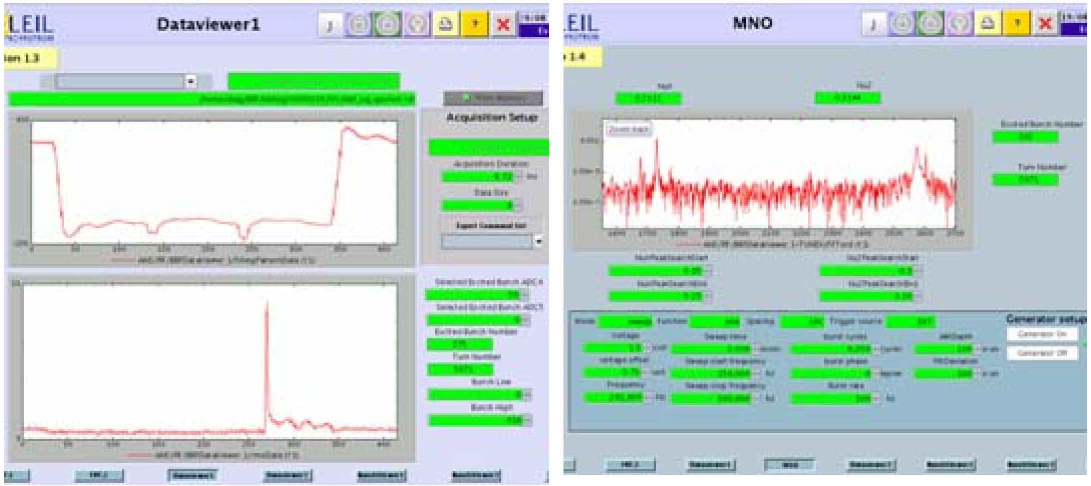
All In-Vac. IDs are now upgraded

Bunch by bunch transverse feedback

- Routinely running in almost all modes of operation: Multi-bunch, single bunch and hybrid (292 mA + 8 mA).
- 2 feedback chains are applied: Chain-1 in the diagonal mode (H and V), and Chain-2 in the pure vertical mode.
- Chain-3 to has just been commissioned in pure horizontal mode
- A bunch is selectively excited to measure the tunes → tune feedback system
- The 2 chains manage to keep the beam stable up to 450 mA, but more efforts required to reach our final goal of 500 mA, due to ions effects.



Feedback completely integrated into the SOLEIL control system

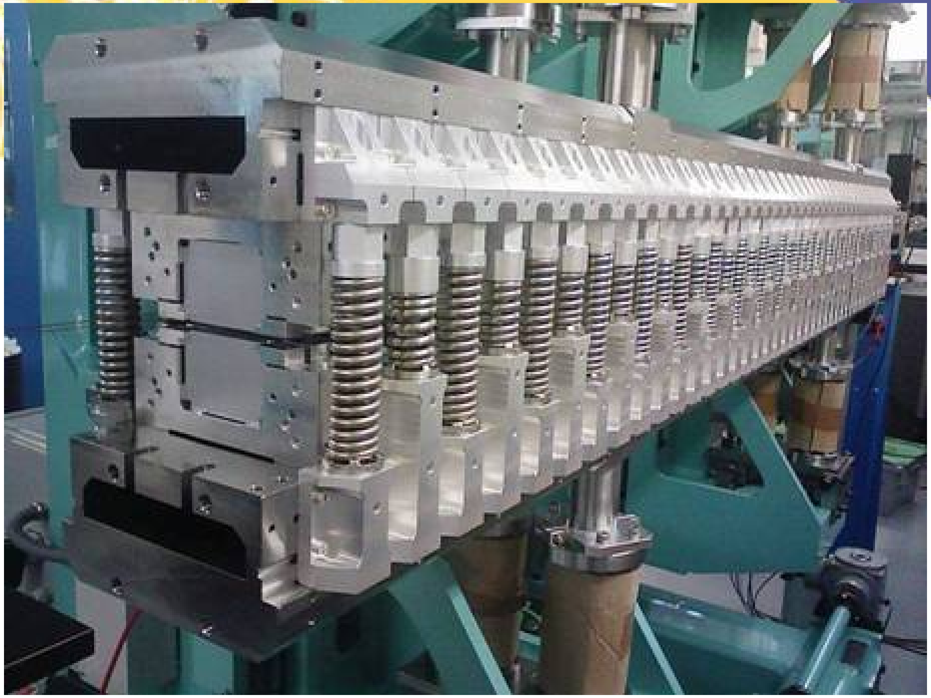


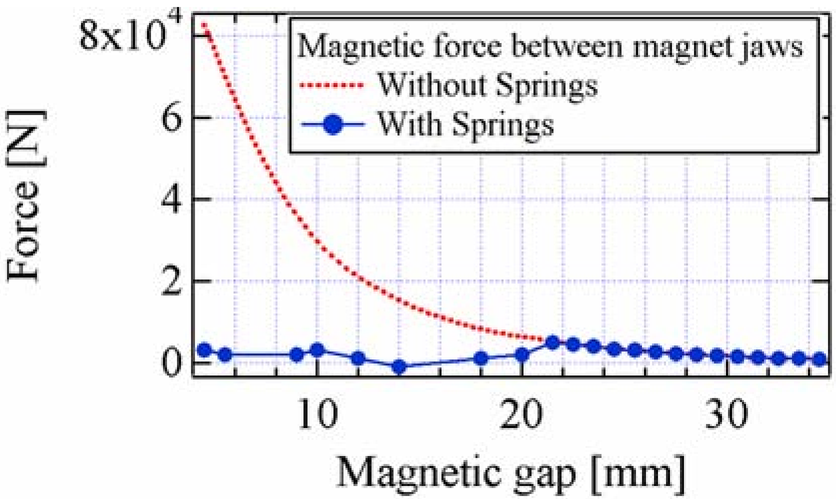
Excitation of a bunch in ¾ filling and its tune spectrum

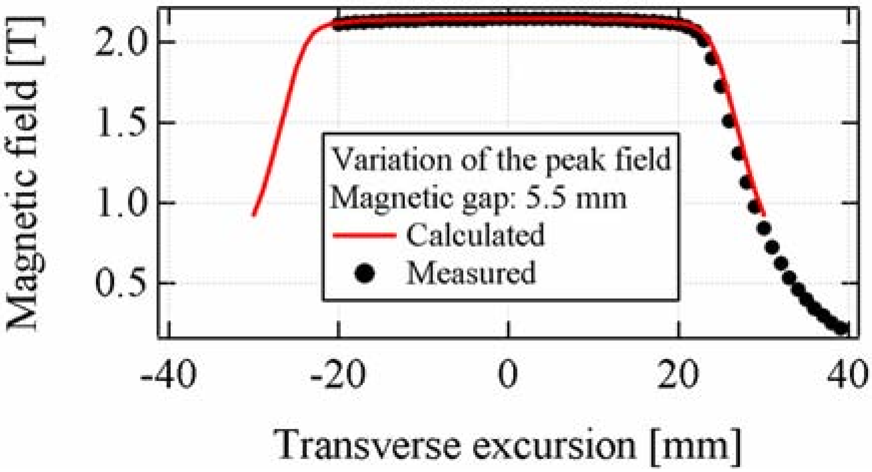
In-vacuum hybrid wiggler

λ= 50mm, N=38, B =2.1 T
Photon energy 20-50 keV
gap 5.5 mm

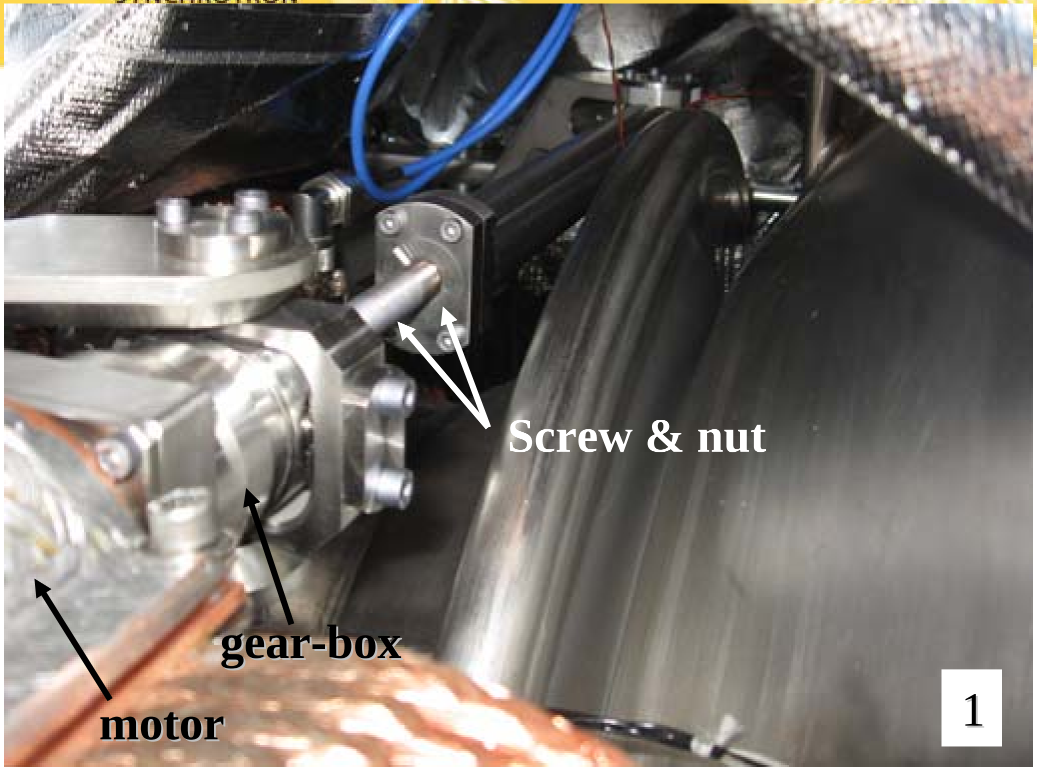
In house development
Innovative magnetic force compensation by springs (8 down to 1 tons)

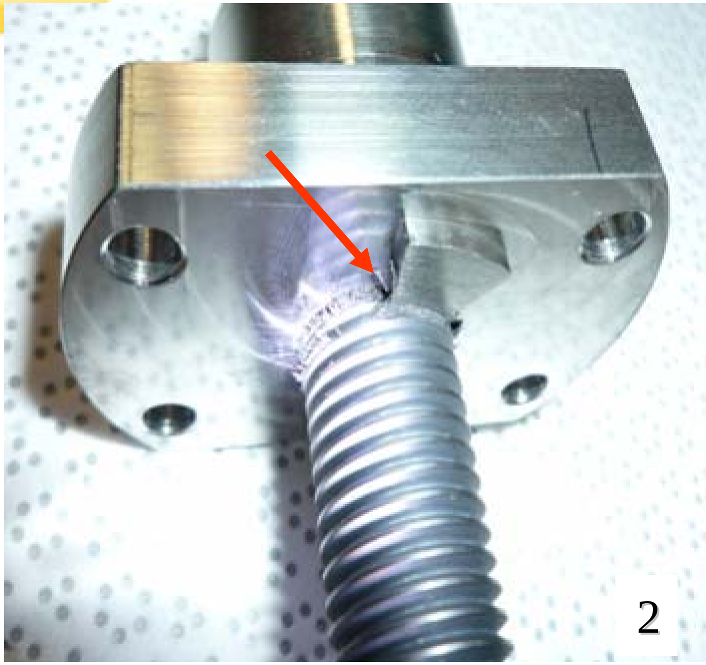


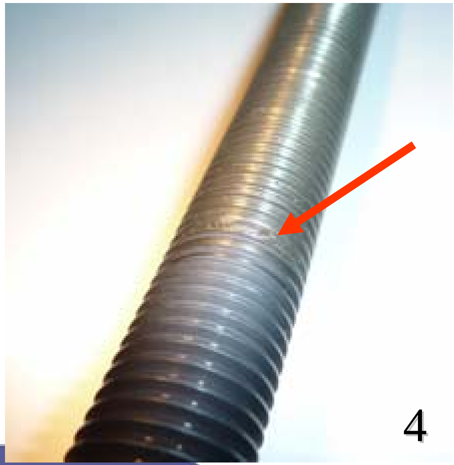




RF system: CM cold tuning system screw damages







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New cold tuning system version

Upgrade CM2 Summer 2009 CM1 January 2010

1) Standard screw-nut assembly replaced by *planetary roller screw*

2) Stepper motor + harmonic drive gear box → **Stepper motor with planetary gear box**

→ Less friction
→ More robust
} **→ Longer lifetime**

Prototype successfully tested on a test bench @ cold in CryHolab at CEA

⟺ 20 years of SOLEIL operation

➢***Cryogenics*: - losses of utilities (electr., water) → few hours restart**
→ Spare compressor station with separarate utilities (beg. 2010)

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Solid state amplifier R & D

- In 2008, transfer of technology agreement concluded with ELTA-AREVA
  → ESRF contract for 7 amplifiers of 150 kW (2 towers of 75 kW)
  First tower to be delivered by the end of 2010

Other projects:

→ ESRF upgrade (replacement of the 352 MHz klystron amplifiers of BO & SR)

- Module 400 W - 476 MHz (Vdc : 50V) → collab. with LNLS: 2 x 40 kW (end 2009)
  f: 350 - 500 MHz, P ~ 400 W, G ~ 20 dB, η ~ 70%

- Higher power modules (Vdc = 50V) → P = 700 W, G > 20 dB, η > 70% @ 350 MHz
  Module validated → run test of a 350 MHz - 10 kW unit (16 mod.), beg. 2010

-[SOLEIL modules (Vdc = 28V) → P = 315 W, G = 13 dB, η = 62 % @ 350 MHz]

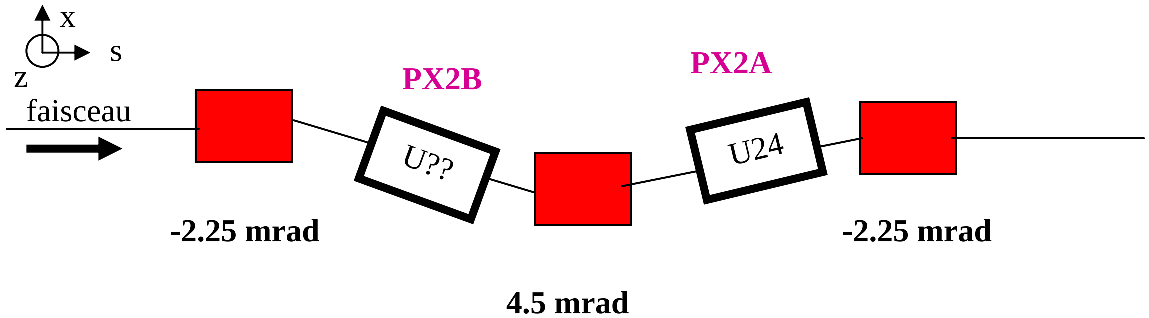
↳ Huge improvement (better performance and Tmax: 130 °C → ~ 70 °C)

New developments (1): 2 distinct BLs in a single medium straight section

↳ canted in-vacuum undulators

Proxima-2

Chicane:
3 permanent magnets

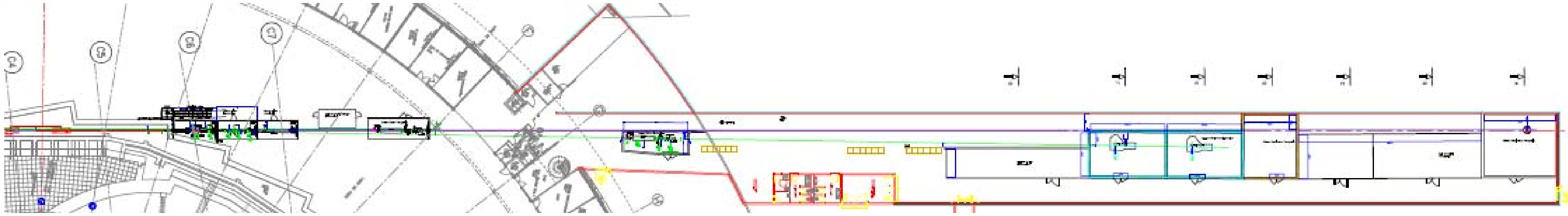


✓Chicane commissioned

- In vac. U24 Jan'10

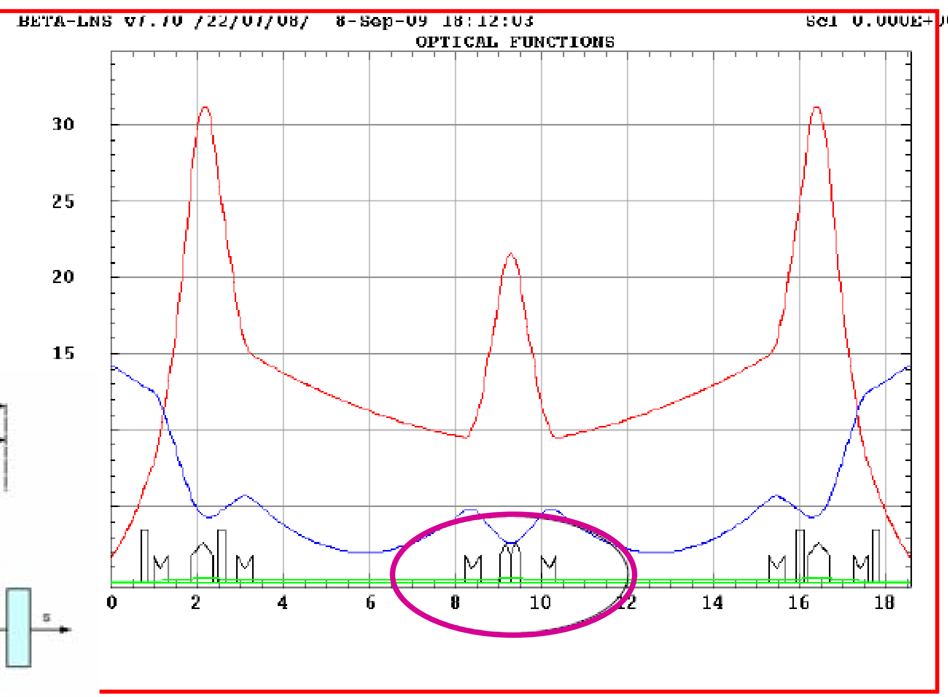
New developments (2): 2 distinct BLs + Double mini-βz in a single long straight section

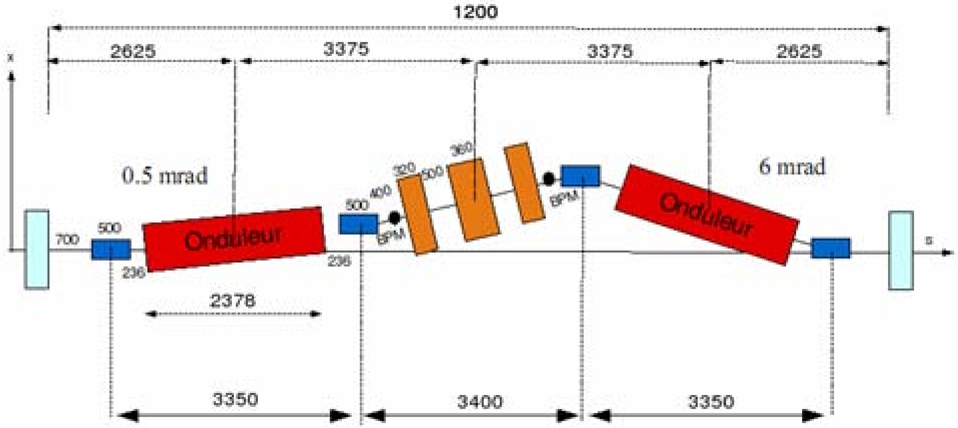
↳ funding for Nanoscopium 150 m long BL (2012), ground breaking in 2010, stability studies under way



2 mini-β_z (8 m → 2 m) to host two low-gap IDs and a chicane

(quadrupole triplet tested. Further Commissioned + breaking of the 4-fold symmetry)





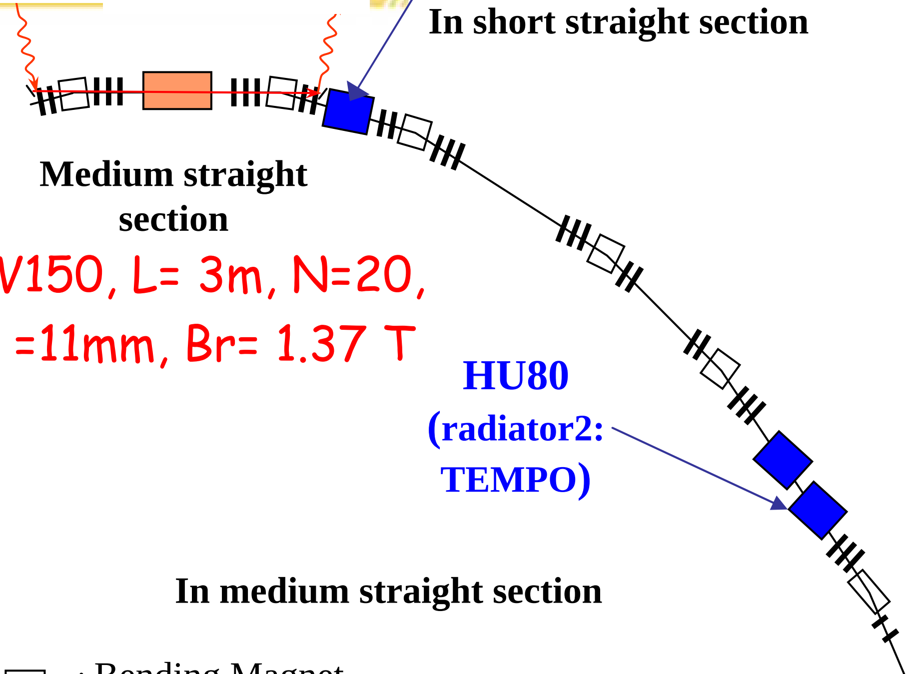
New development (3) : Femto-slicing project (end 2010)
horizontal separation w/o modifying the SR optics

laser

Modulator

U20 (radiator1: CRISTAL)

In short straight section



Medium straight section

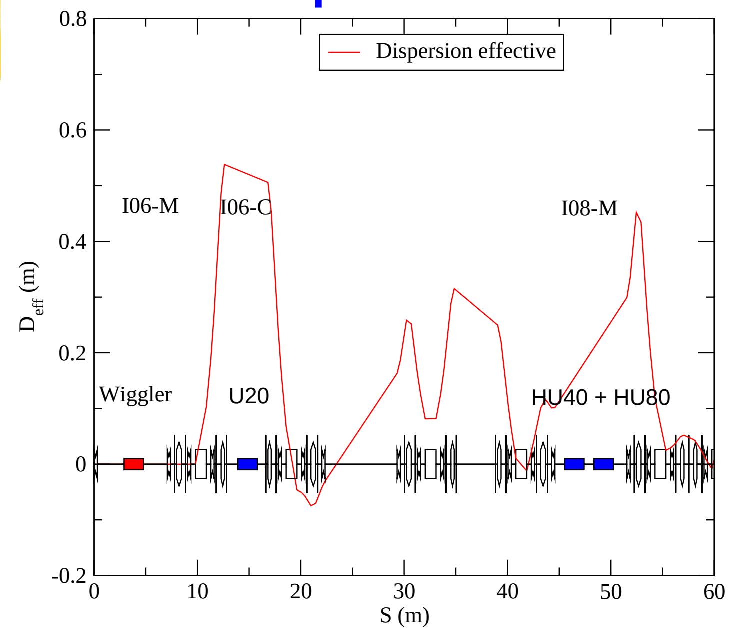
W150, L= 3m, N=20, g =11mm, Br= 1.37 T

HU80 (radiator2: TEMPO)

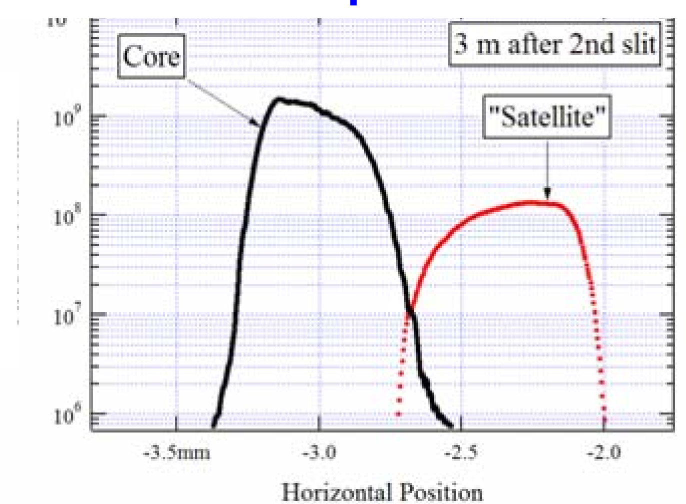
In medium straight section

: Bending Magnet

Electron separation scheme



Photon separation



Laser specification (5 mJ, 800 nm, 30 fs FWHM, 10 kHz)

→ $\Delta E = \pm 14$ MeV viz. $\Delta E/E \approx \pm 0.5\% \approx \pm 5\ \sigma_E$ at 2.75 GeV

Expected bunch length ~ 100 fs

Buildings and Research centers

- **Extension of the Guest House (2,3 M€, 2009-2010)**
  → Double the hosting capacity (40 → 80 rooms)

- **New Technical building (1.9 M€, 2010-2011)**

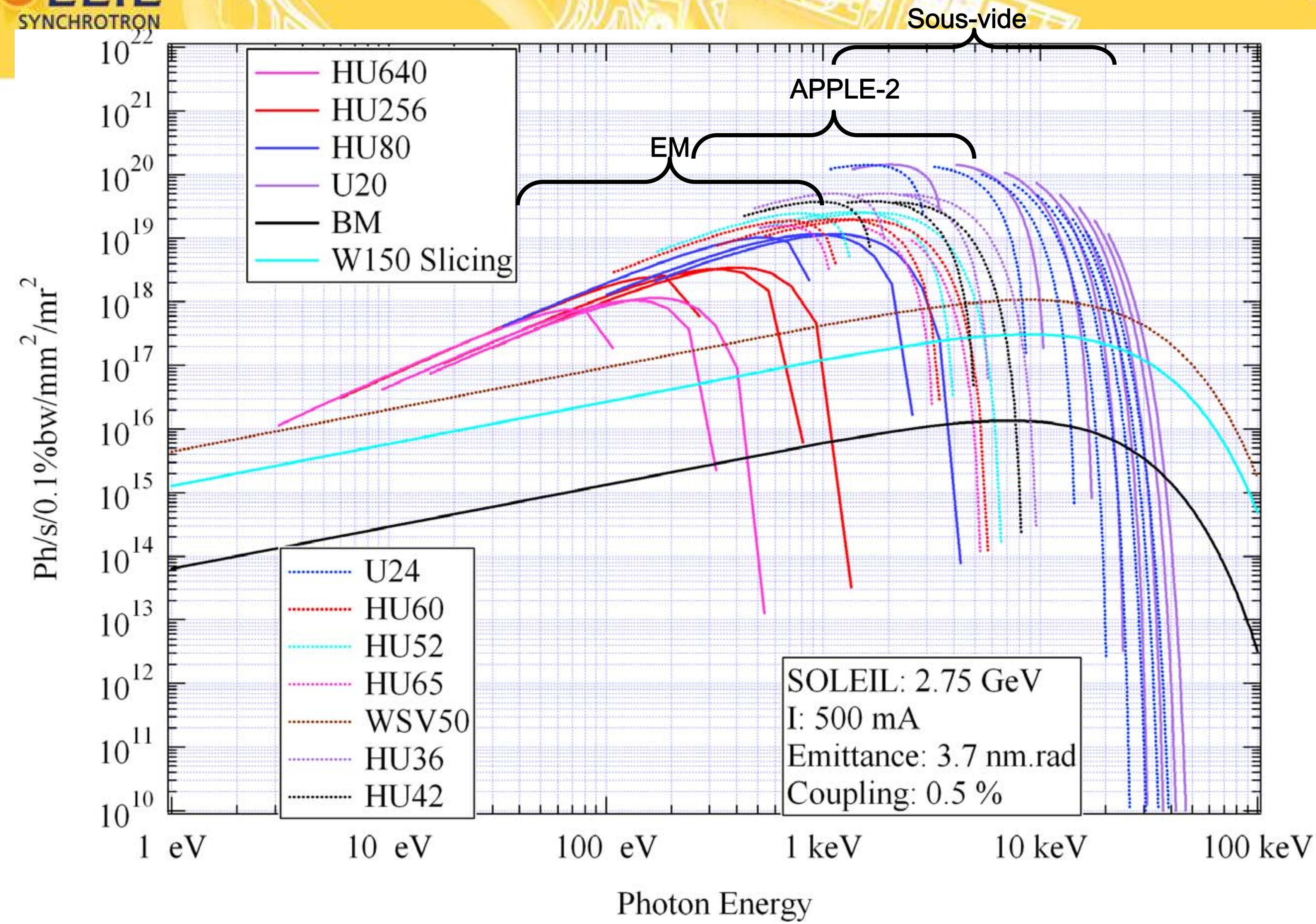
- **IPANEMA (1812 m^2, 2x4.5 M€) Building 2010**
  (Institut Photonique d'Analyse Non-destructive Européen des Matériaux Anciens)
  - A beam line for ancient material
  - one dedicated to **hard X-ray micro-tomography**, the other to **μm scale hard X-ray spectro-microscopy**.
  - The platform aims at supporting users from the fields of **archaeology**, **palaeontology**, **conservation** and **past environments sciences** and at contributing to the development of new analytical methodologies for these fields. **A new synchrotron beam-line will be set up and operated** in the framework of the platform. IPANEMA will consist of a core team of 15 technicians, engineers and scientists and will host up to 25 external researchers primarily in the framework of short- to mid-term research projects.

Extra slides

Storage Ring main parameters

Energy	2.739	GeV
Circumference	354.097	m
RF frequency	352.196	MHz
Harmonic number	416	
Betatron tunes (H/V)	18.202 /10.317	
Natural chromaticities (H/V)	-53 / -23	
Chromaticities (H/V)	2/4	
Momentum compaction α_1 / α_2	4.5×10^{-4} /4.6 10^{-3}	
Radiation loss per turn (with IDs)	1200	keV
Damping times	7, 7, 3.5	ms
Emittance	3.7	nm.rad
Relative energy spread	1.016×10^{-3}	
Natural bunch length (@ 3.4 MV)	4.3	mm
Coupling (w/o IDs)	0.8	%
Multi-bunch mode	300	mA
Beam Lifetime (w/o IDs)	16	h

BRILLANCE


Sous-vide
APPLE-2
EM
HU640
HU256
HU80
U20
BM
W150 Slicing
U24
HU60
HU52
HU65
WSV50
HU36
HU42
SOLEIL: 2.75 GeV
I: 500 mA
Emittance: 3.7 nm.rad
Coupling: 0.5 %
Ph/s/0.1%bw/mm^2/mr^2
10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} 10^{22}
1 eV
10 eV
100 eV
1 keV
10 keV
100 keV
Photon Energy

Built Insertion Devices

4 (+1) in-vacuum, 9 Apple 2, 4 EM IDs

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Version 2.0

(1) ID ready to be installed

	HU640	HU256	HU80	HU60	HU52	HU44	U24	U20
Beam Line	DESIRS	CASSIOPEE PLEIADES ANTARES	TEMPO PLEIADES MICROFOC	ANTARES CASSIOPEE	DEIMOS LUCIA	TEMPO MICROFOC	PROXIMA2 (1)	PROXIMA1 SWING CRISTAL SIXS GALAXIES (1)
Quantity	1	3	3	2	2	2	1	4
Period [mm]	640	256	80	60	52	44	24	20
Period #	14	12	19	26	30	36	81	98
Type	EM	EM	Apple-II	Apple-II	Apple-II	Apple-II	Hybrid in-.vac	Hybrid in-vac.
gap [mm]	19	50 (H) 15 (V)	15.5 - 250	15.5 - 250	15.5 - 250	15.5 - 250	5.5 - 30	5.5 - 30
Polarization	Lin. (0-90°) / E	LH / LV / E	Lin. (0-90°) / E	Lin. (0-90°) / E	Lin. (0-90°) / E	Lin. (0-90°) / E	LH	LH
Peak field [T]	0.09 (H) 0.11 (V)	0.33 (H) 0.44 (V)	0.72 (H) 0.94 (V)	0.82 (H) 0.57 (V)	0.74 (H) 0.50 (V)	0.64 (H) 0. 41 (V)	0.84	0.95
Quasi-Periodic	N	Y/ N	Y	N	N	N	N	N
Energy (keV)	0.005 - 0.04	0.01 - 1	0.04 - 1.6	0.1 - 4	0.5 - 6	1 - 8	3 - 18	3 - 18

SOLEIL SYNCHROTRON

Insertion Devices to be build

Version 2.0

	HU36	HU42	HU64	U20	U??	EMPHU65	WSV50	W150?
Beam Line	SIRIUS	MICRO-XMOUS	MICRO-XMOUS	NANO-SCOPIUM	PROXIMA2	DEIMOS	PSICHE	PUMA + SLICING
Quantity	1	1	1	2	1	1	1	1
Period [mm]	36	42	64	20	26?	65	50	150?
Period #	44	38	24	98	73?	26	38	13
Type	Apple-II	Apple-II	Apple-II	Hybrid In-vac.	Hybrid In-vac.	Electro Aim. Perm	Hybride sous vide	Hybride hors vide?
gap [mm]	11 - 250	15.5 - 250	15.5 - 250	5.5 - 30	5.5 - 30	15.5	5.5 - 30	11 - 30?
Polarization	Lin. (0-90°) / E	Lin. (0-90°) / E	Lin. (0-180°) / E	LH	LH	LV / E	LH	LH
Peak field [T]	0.75 (H) 0.53 (V)	0.64 (H) 0. 41 (V)	0.82 (H) 0.57 (V)	0.95	0.78?	0.24 (H) 0.24 (V)	2.1	2.1?
Quasi-Periodic	N	N	Y	N	N	N	N	N
Energy (keV)	2 - 1	1 - 8	0.1 - 4	3 - 18		5 - 17	20 - 50	1.3 - 1.5

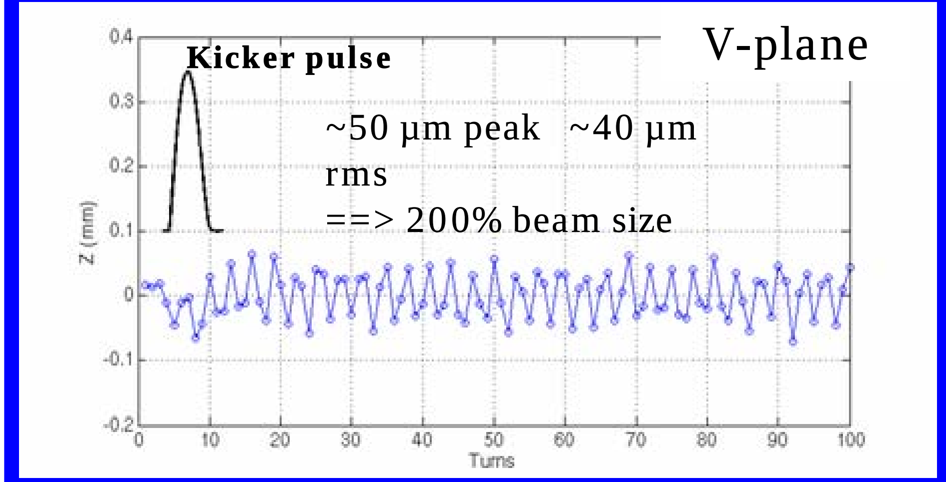
SOLEIL SYNCHROTRON

« Top-Up »: injection distortion

Closed orbit distortion induced by pulsed magnets during injection:
In 2006: 1 mm in H-plane and 0.2 mm in V-plane peak to peak (damped down after 5 ms).

- Fringe field of thin septum reduced down to <2µT.m (10^{-5} main field).

- **Thick septum shielding**
  ➔ *3% σ_x and 50% σ_z*
  and identity of the 4 kicker pulsed magnets
  ➔ *20% σ_x et 200% de σ_z*



- 10% stability seem reachable in H-plane. A feedforward in V-plane using a pulse magnet is likely to happen.

- BLs can use a trigger signal to gate their detectors during injection process