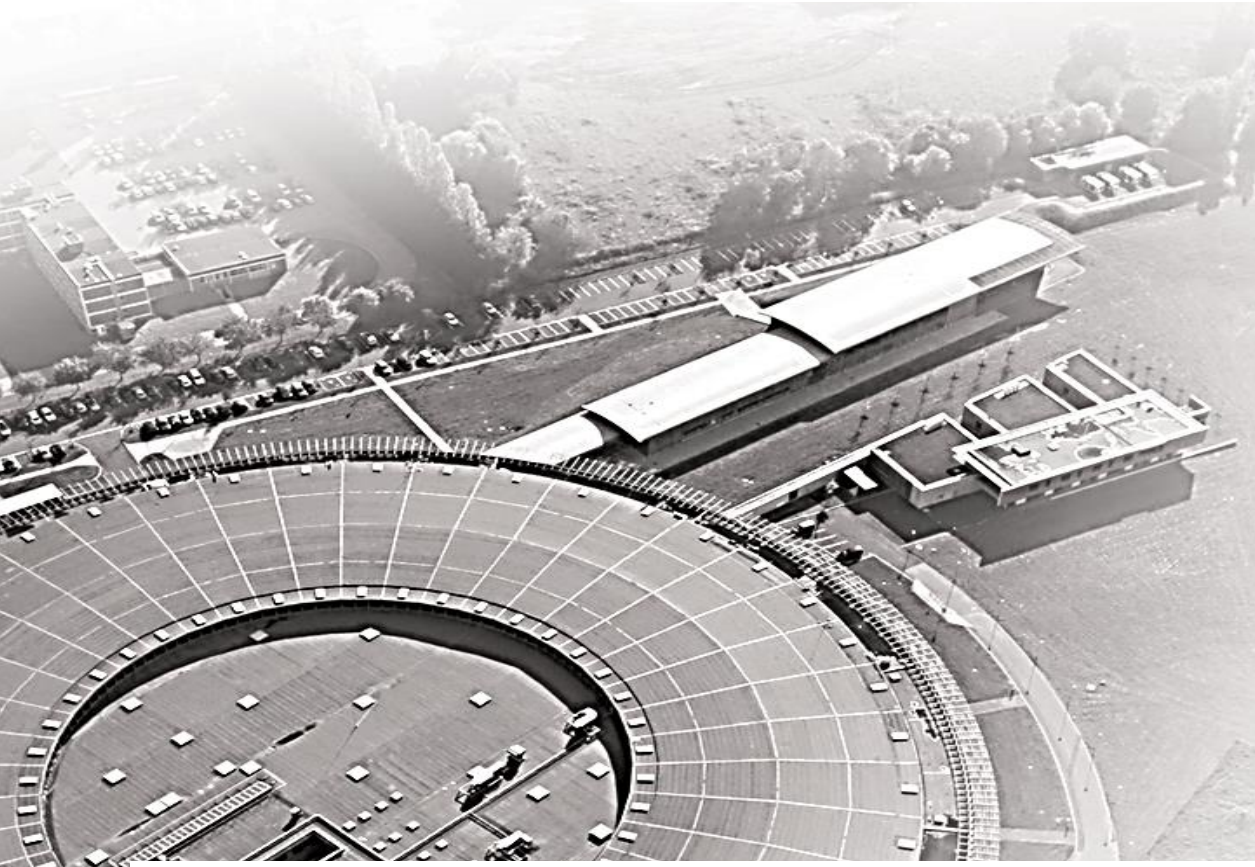
Status of SOLEIL



R. Nagaoka, L. Nadolski

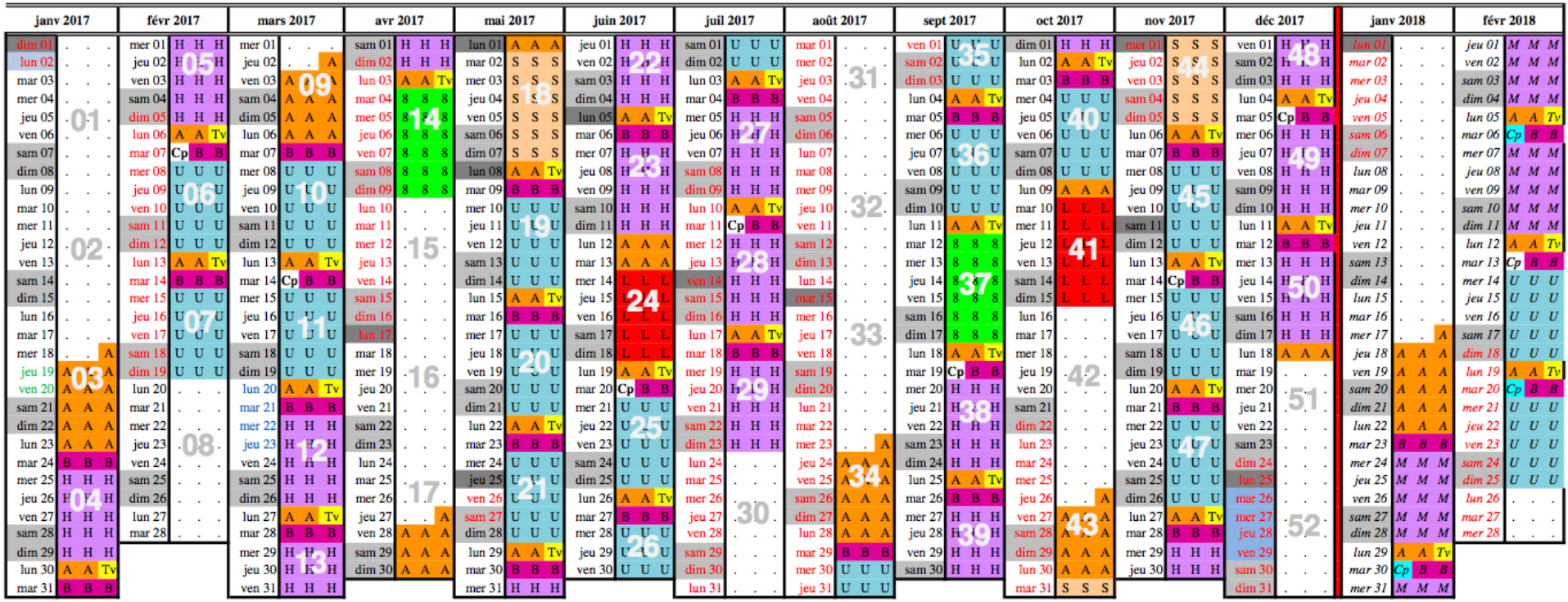
On behalf of the Accelerators and Engineering Division

Layout of the presentation

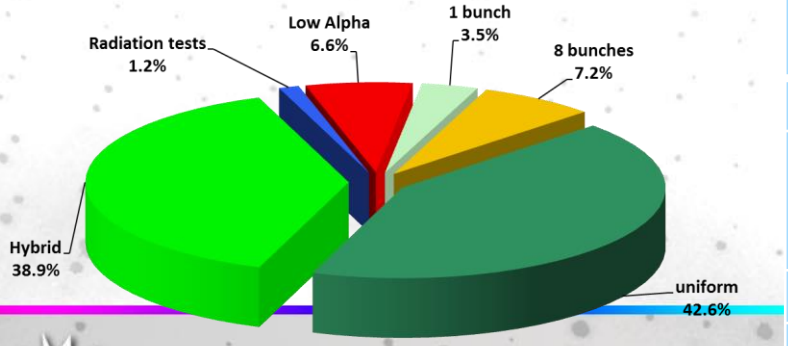
- SOLEIL metrics
- Achievements
- Major failures
- On-going projects
- Upgrade at a glance
- Roadmap for 2018

Beam time schedule in 2017

5091 hours for the beamlines.



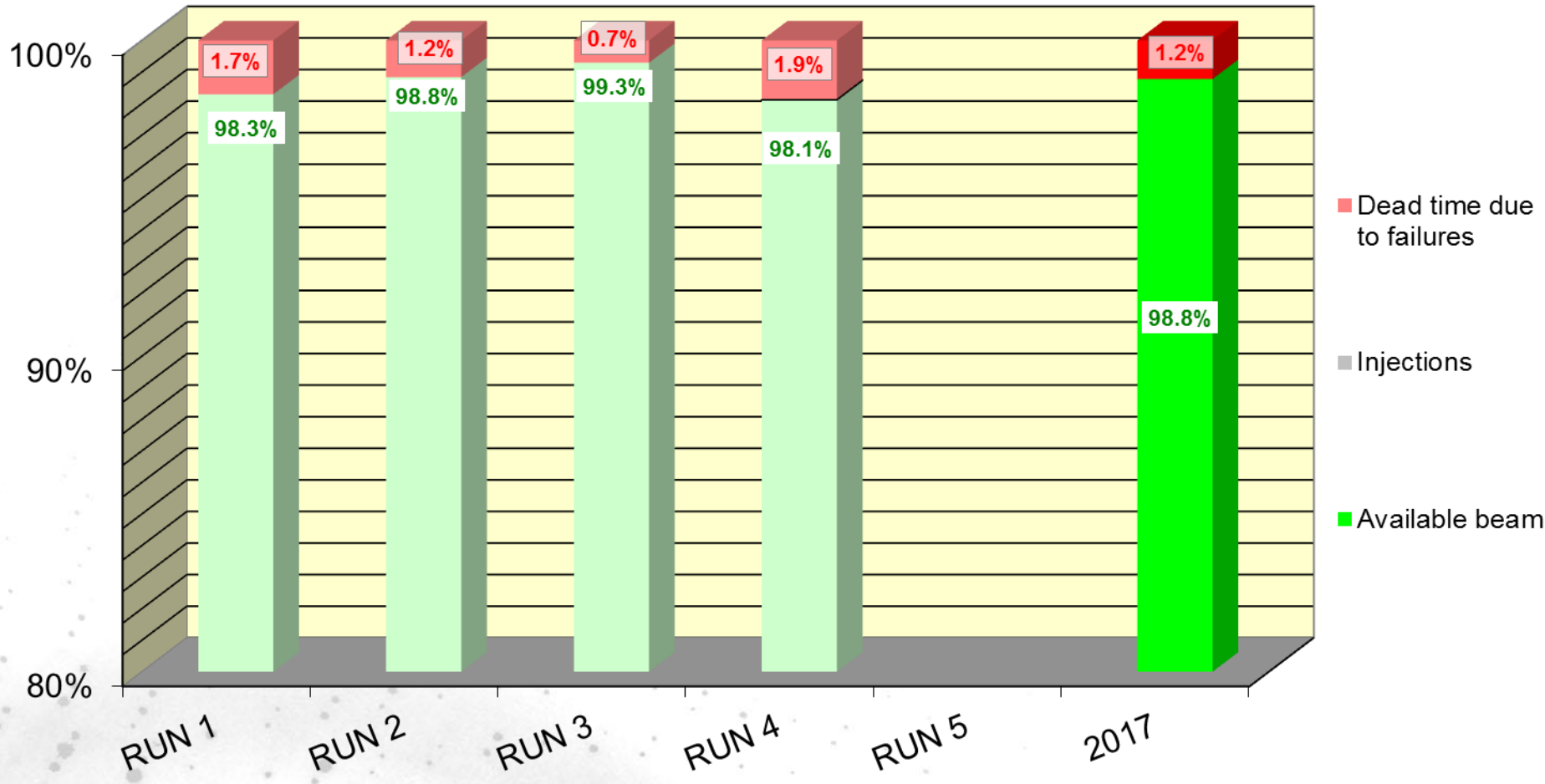
A: accelerator White: shut down



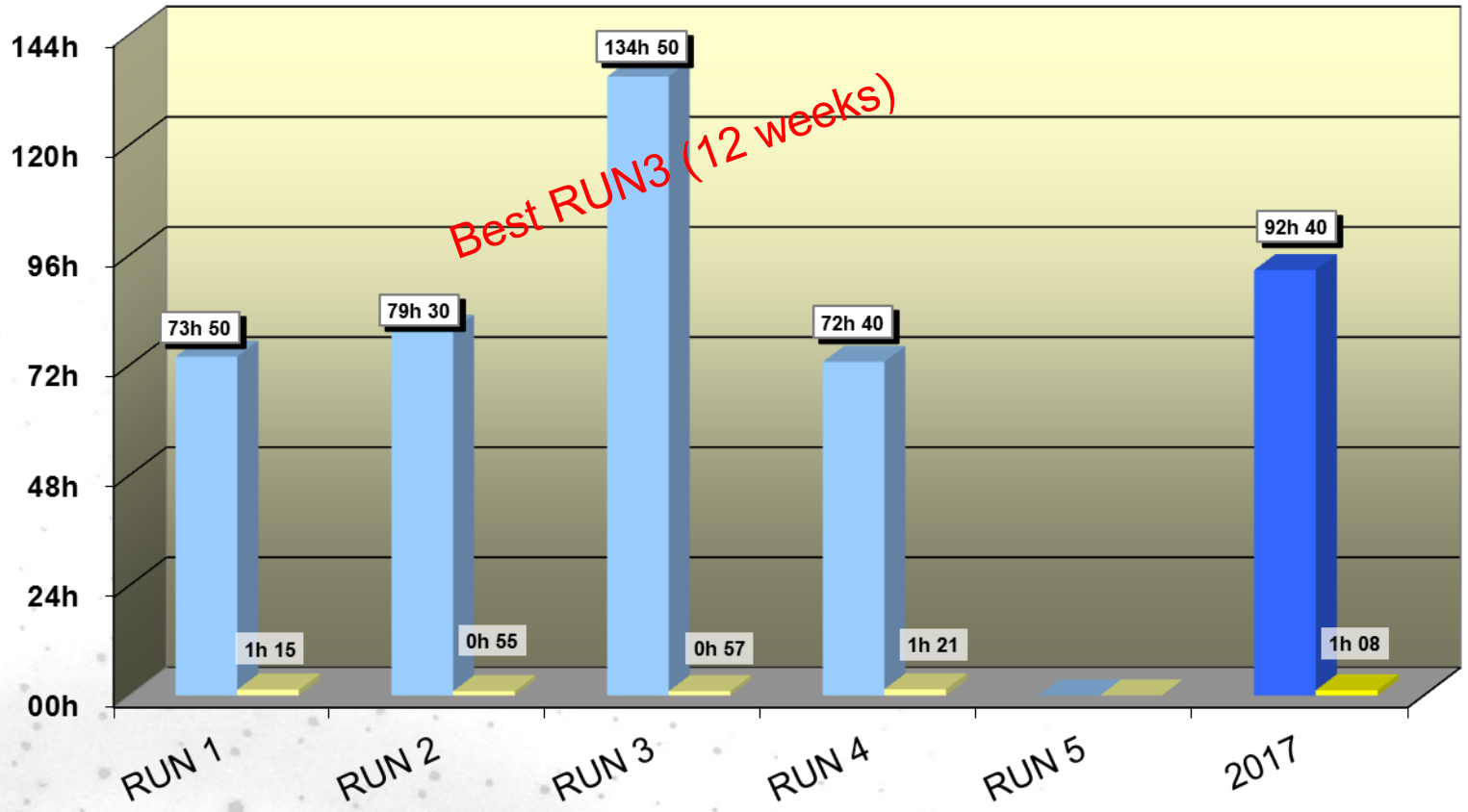
Mode of operation Bunch fill. patterns	User Operation in 2017	Ultimate performance achieved
Multibunch (M2)	500 mA	500 mA
Hybrid/camshaft mode (M)	425 mA + 5 mA	425 mA + 10 mA
	+ Slicing on high intensity bunch	Slice length < 200 fs FWHM
8 bunches (8)	100 mA	110 mA
1 bunch (S)	16 mA	20 mA
Low-α Hybrid mode (L)	4.7 ps RMS for 65 µA	< 3.2 ps RMS for 15 µA

All in top-up mode

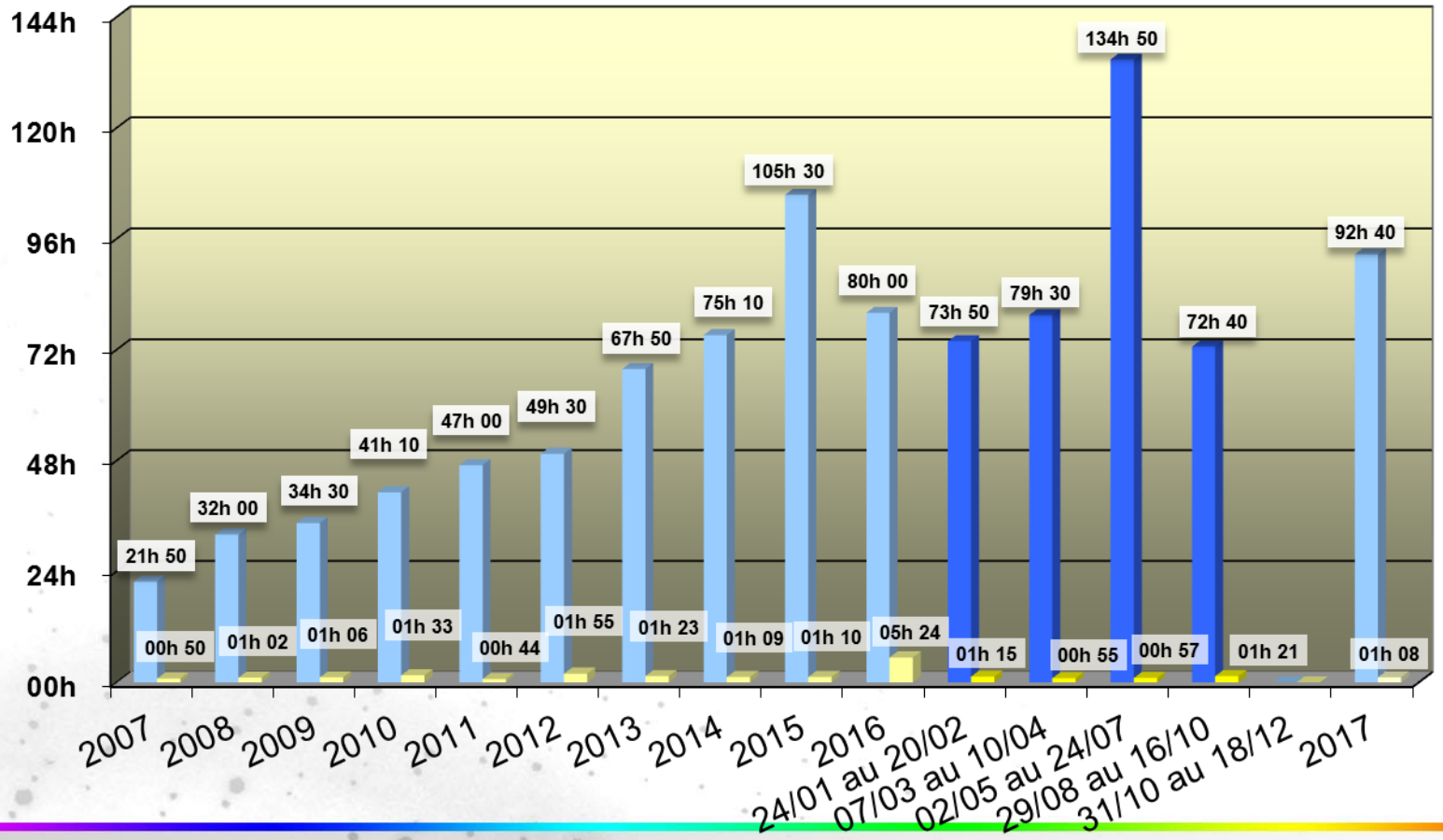
Photon Beam Availability
(2017: Run1 to Run4 out of 5)



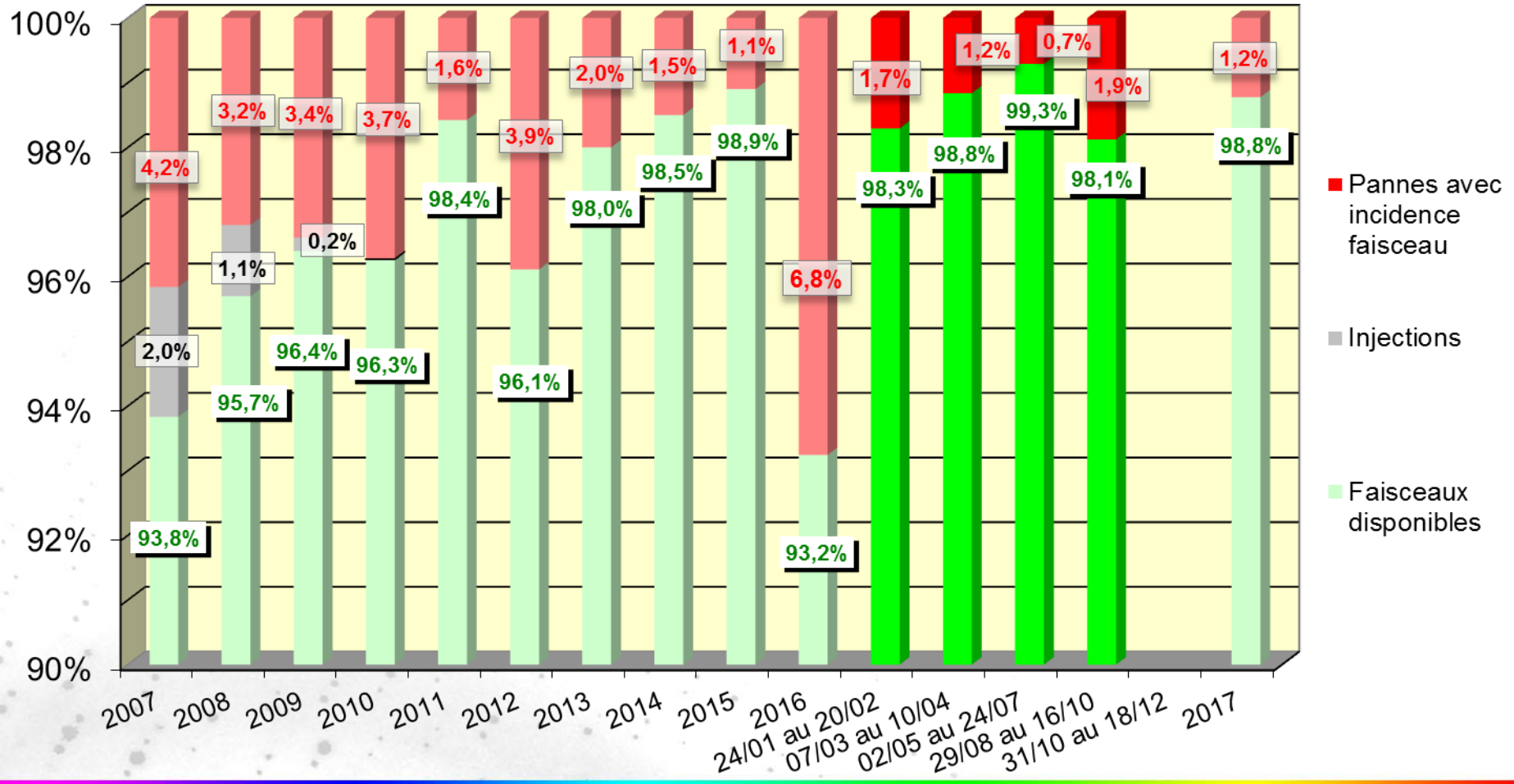
MTBF (Mean Time Between Failures) & MTTR (Mean Time To Recovery) during beamlines and RP sessions in 2017 (Run1 to Run4)



MTBF: Temps moyen entre 2 pannes (92h40)
et MTTR: temps moyen d'une interruption faisceau (01h08)
durant les sessions Lignes et RP sur l'année 2017



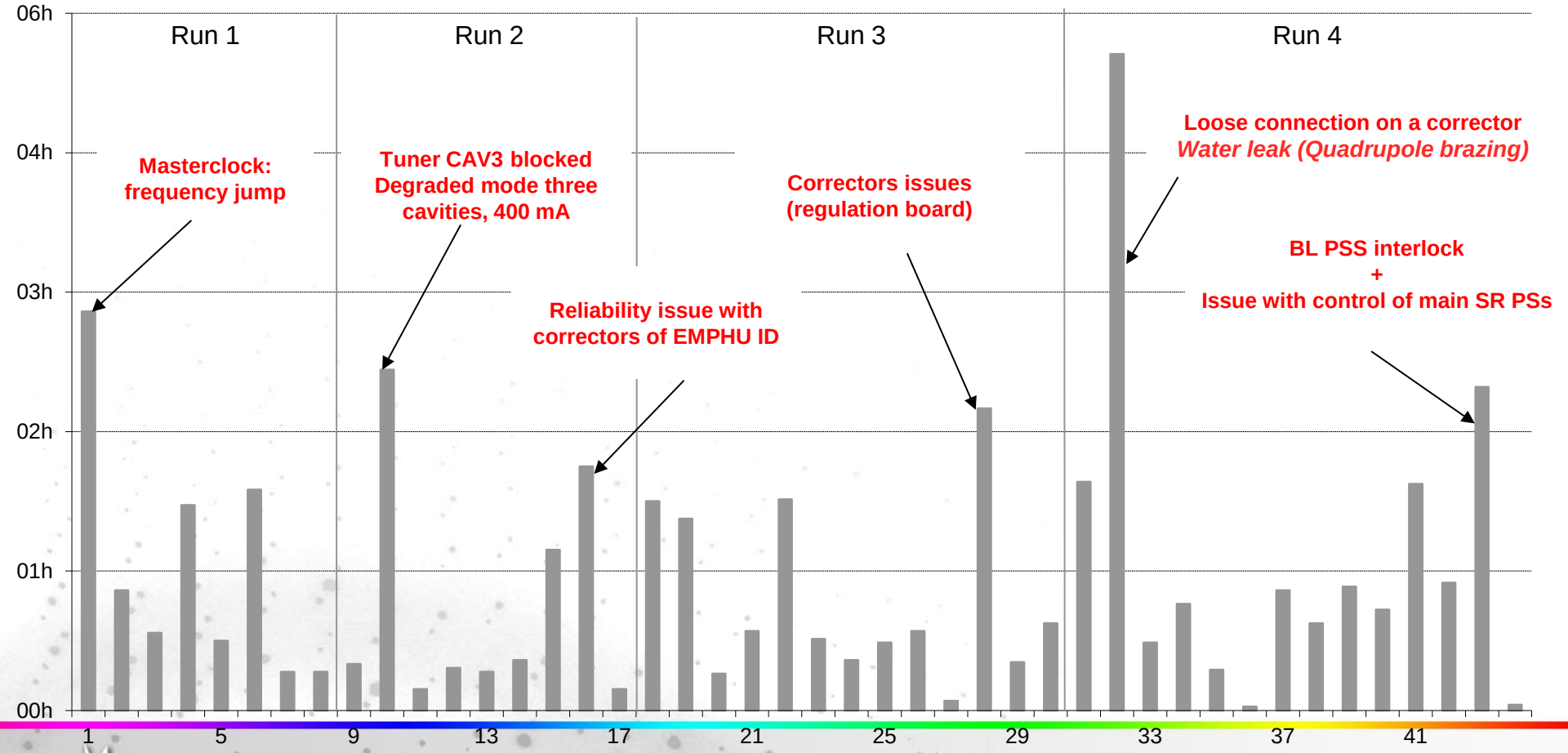
Efficacité durant les sessions Lignes et RP sur l'année 2017
4027 heures de faisceau ont été délivrées
soit 98,8 % du temps de faisceau programmé



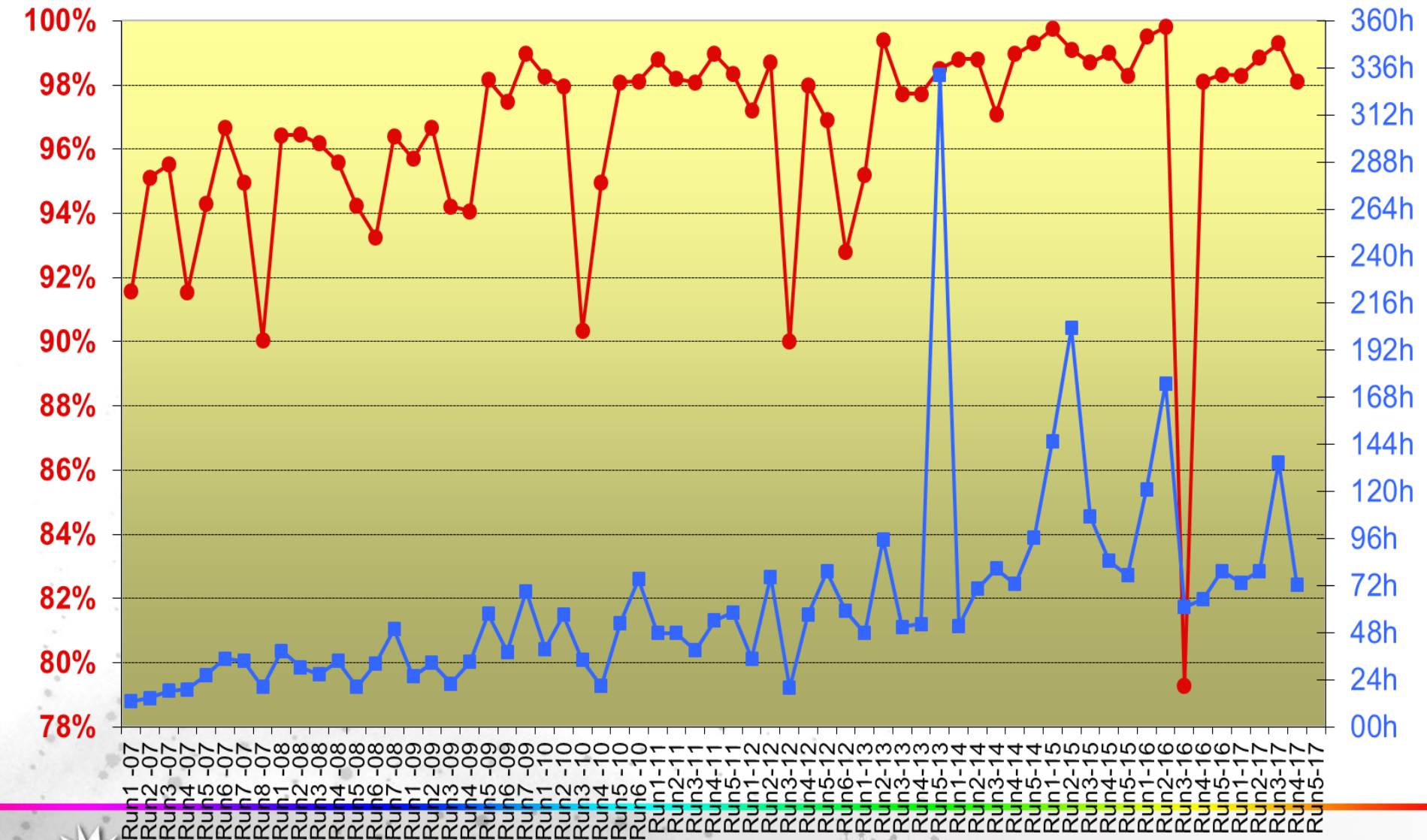
Duration of every interruption (Run 1 to 4)

Time duration of the 44 beam interruptions (beam losses or equipment failures) impacting the beamline or Radiation Safety Tests

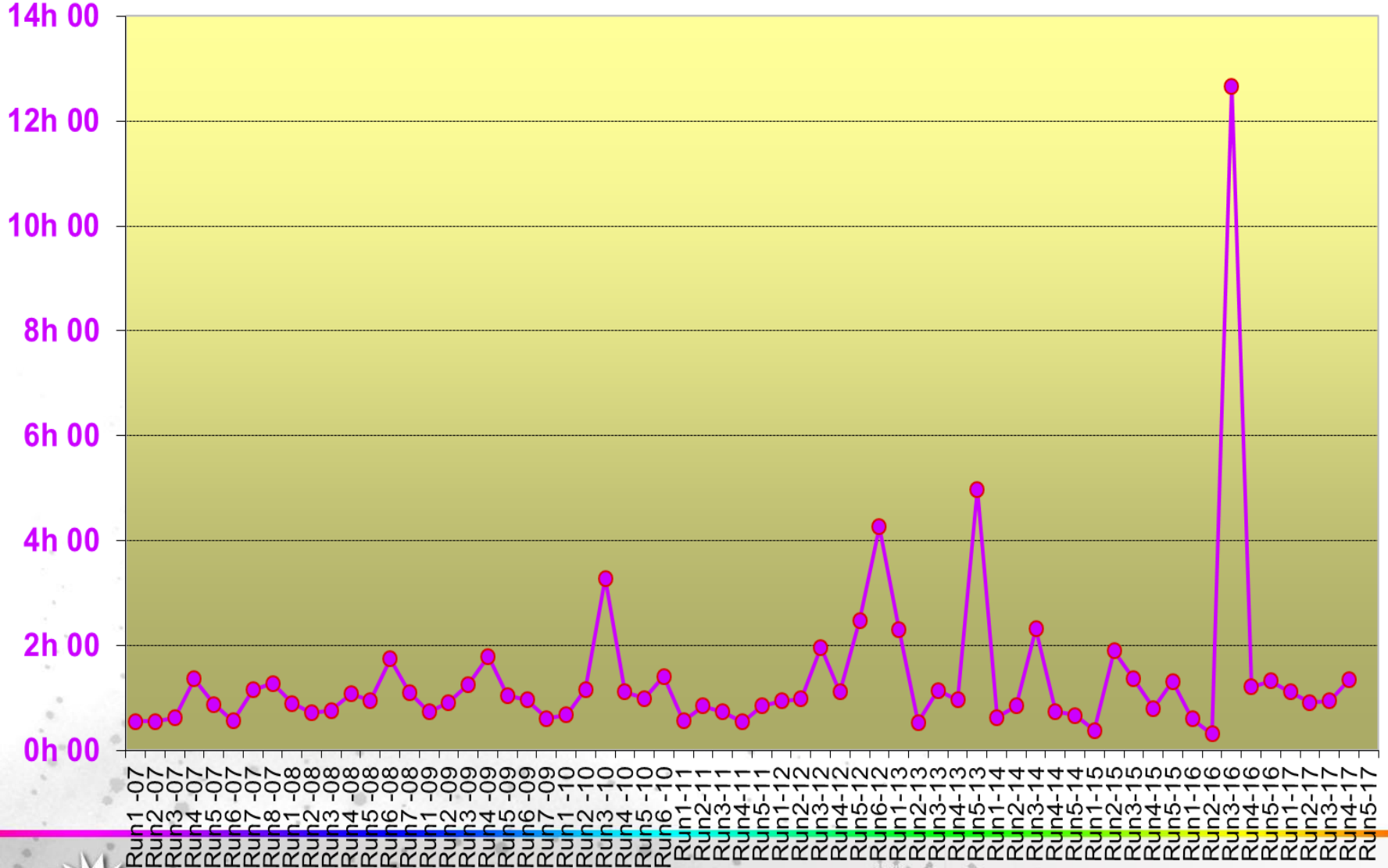
Total 49:55
Min 00:02
Max 05:39
Mean 01:08
RMS 01:05



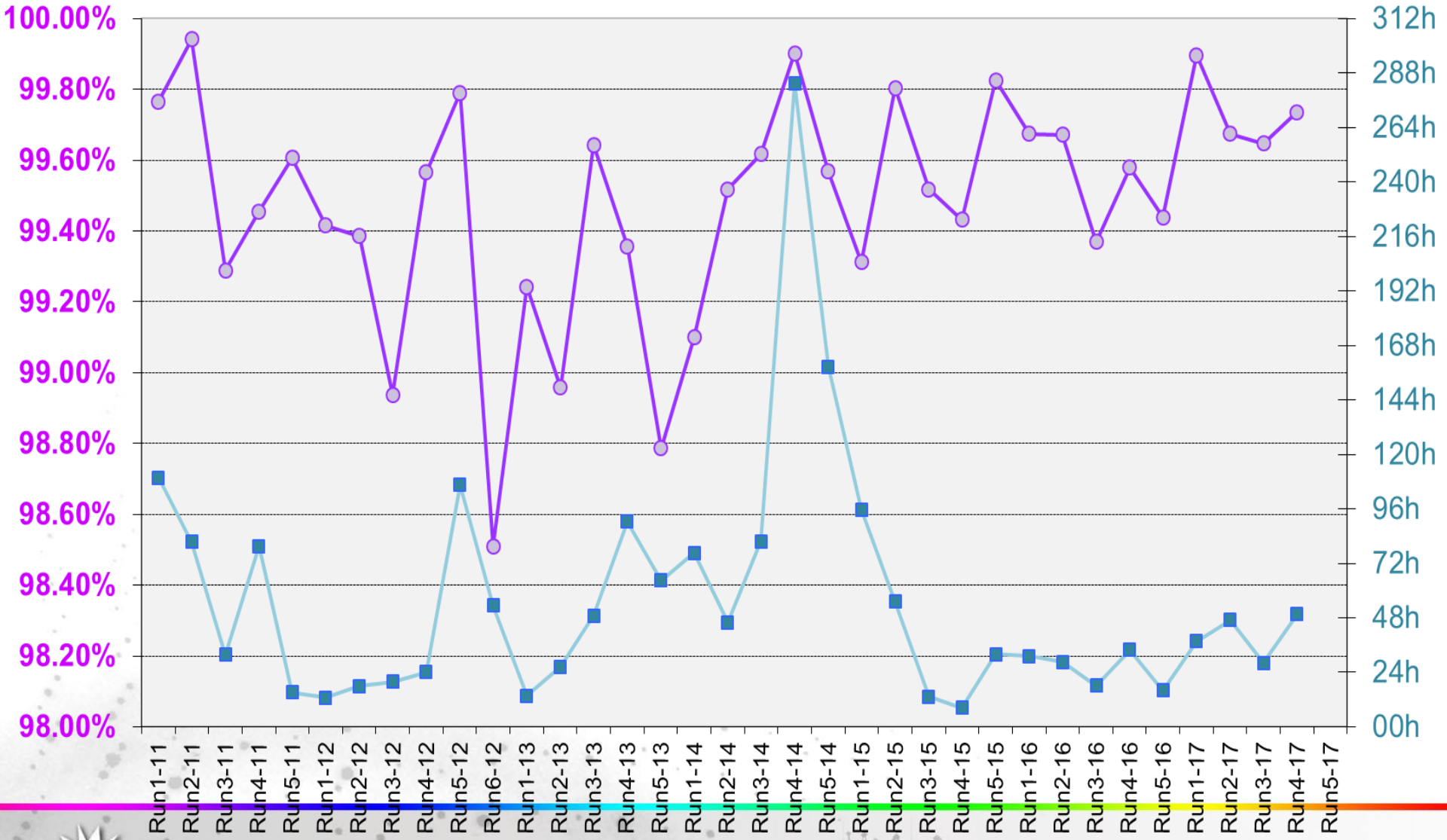
Efficacité et MTBF par RUN durant les sessions Lignes et RP de 2007 à 2017



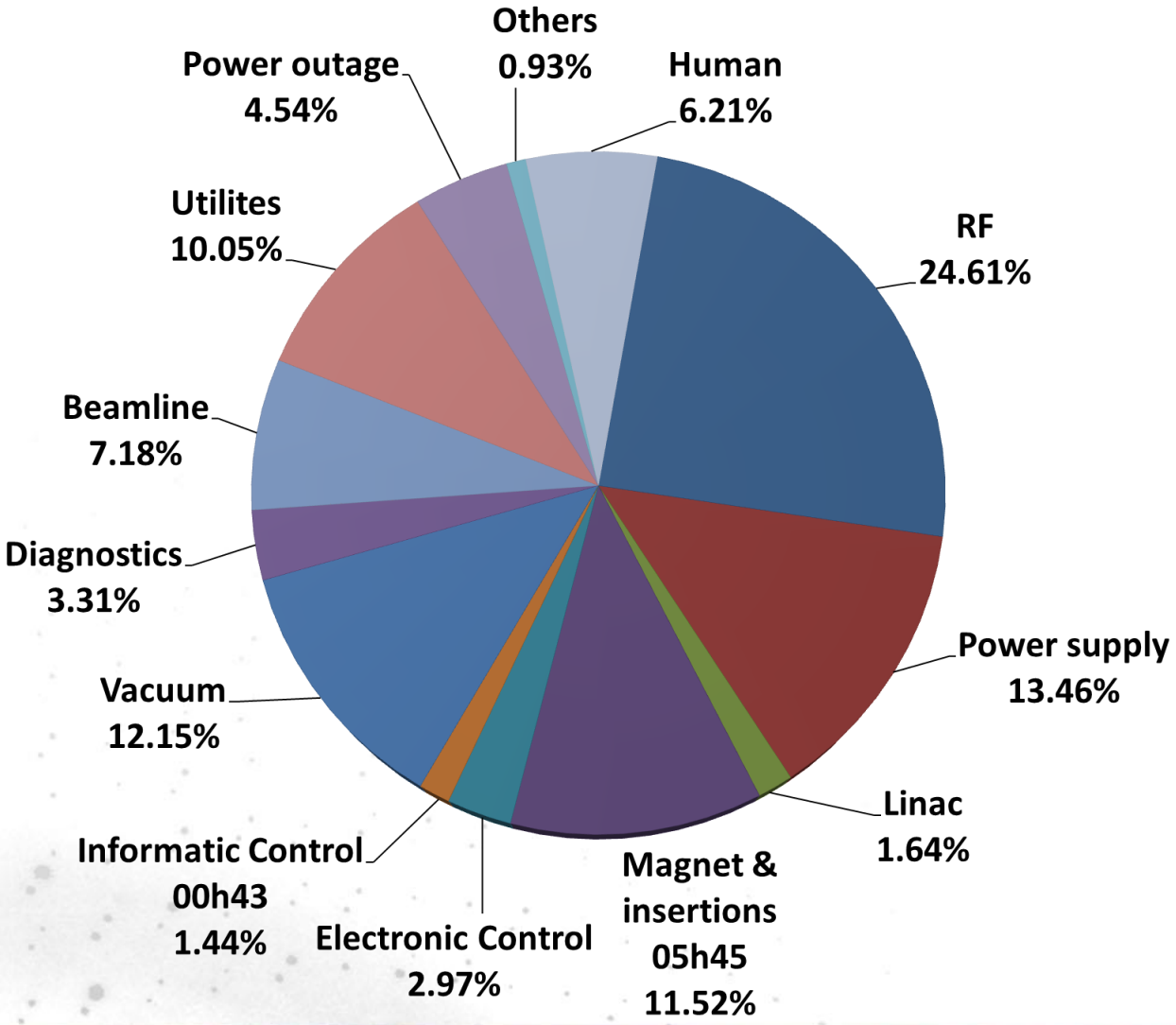
MTTR par RUN
durant les sessions Lignes et RP
de 2007 à 2017

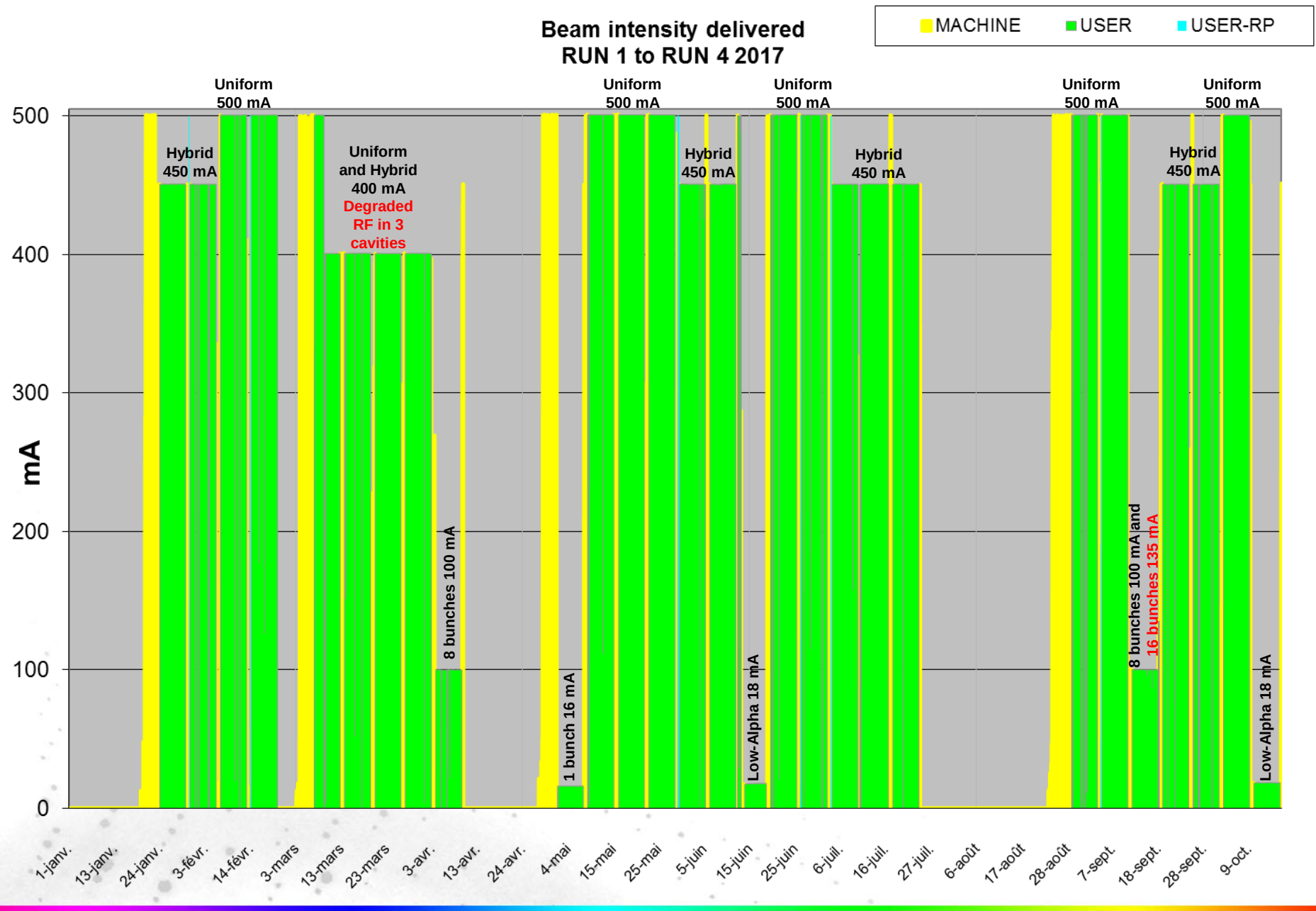


Efficacité et MTBF du TOP-UP durant les sessions Lignes et RP par RUN de 2011 à 2017



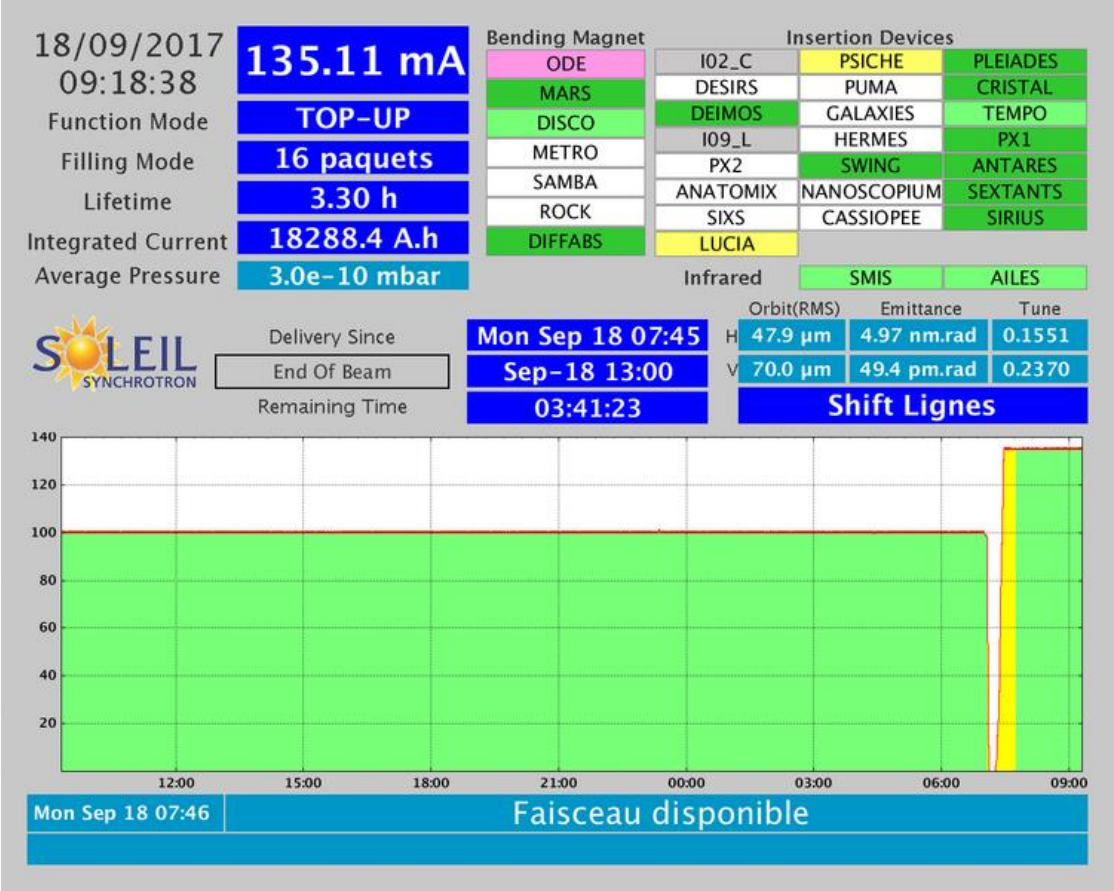
Origin of the 46 hours Beam time LOST in 2017 (RUN1 to RUN4)



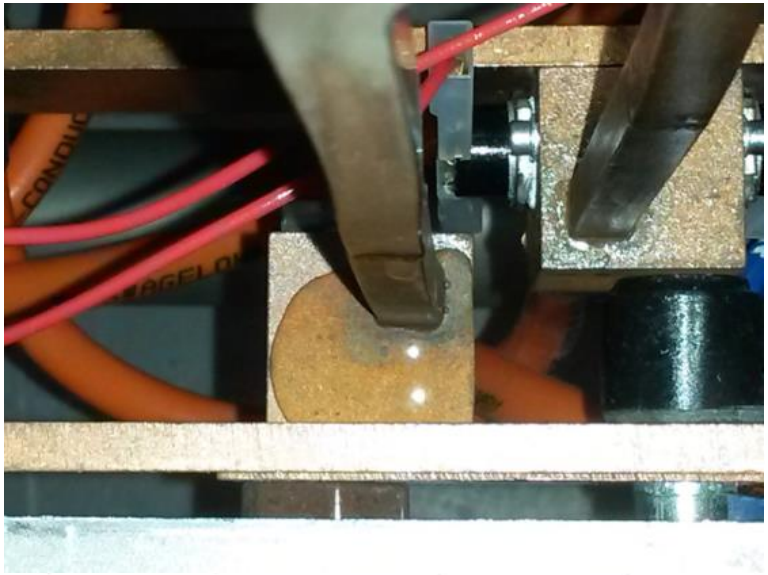

Beam intensity delivered
RUN 1 to RUN 4 2017
MACHINE
USER
USER-RP
mA
500
400
300
200
100
0
Uniform 500 mA
Hybrid 450 mA
Uniform and Hybrid 400 mA
Degraded RF in 3 cavities
8 bunches 100 mA
1 bunch 16 mA
Low-Alpha 18 mA
8 bunches 100 mA and 16 bunches 135 mA
1-janv.
13-janv.
24-janv.
3-févr.
14-févr.
3-mars
13-mars
23-mars
3-avr.
13-avr.
24-avr.
4-mai
15-mai
25-mai
5-juin
15-juin
25-juin
6-juil.
16-juil.
27-juil.
6-août
17-août
28-août
7-sept.
18-sept.
28-sept.
9-oct.

16 bunch filling pattern

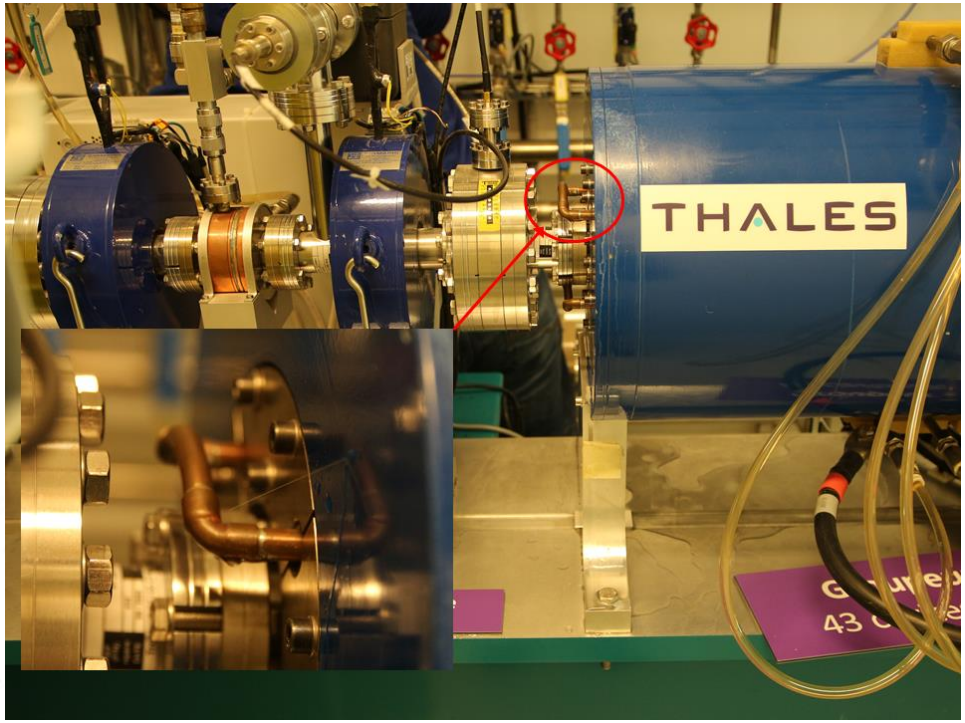
- A **new filling** pattern for time resolved experiment
- Total current:130 mA, 3.5 h, 1% coupling, top-up
- Tested in September 2017



Major Failures:
Several solder/welding water leaks

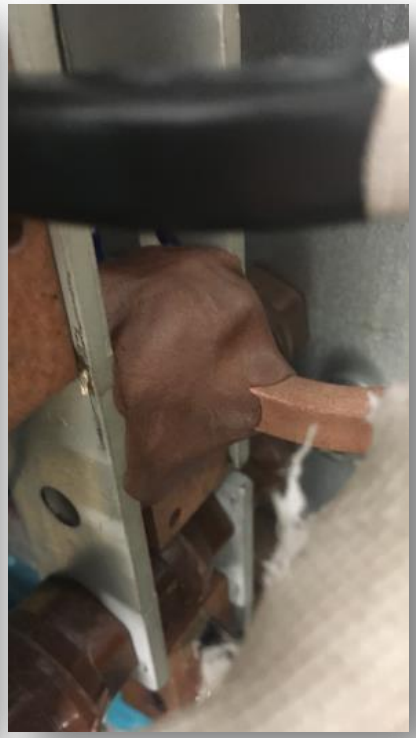


Water leak on coil 45 of the
Electromagnetic HU640 ID



LINAC buncher
A pinhole size water leak in cooling circuit

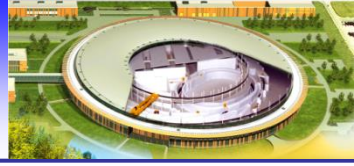
Water leak on a quadrupole connection



Aging facility (10 – 15 year old equipment)
Cu concentration if carefully follow as in indicator of corrosion
Cu is collected by resin
Not monitoring or control of dissolved O_2 rate

What is the experience of other facilities?

Main RF activities



SOLEIL RF SYSTEMS

1) Refurbishment of the SR 180 kW SSPA's (new transistor & upgrade of the 2.5 kW combiners)
- Ampli_1 (4 towers) completed ; going on at rate of 2 towers a year → 2022
- + 10 % efficiency → investment cost compensated in ~ 3 years

2) The last of the four new SR cavity input couplers was implemented in January; all of them were tested up to 260 kW with beam during 2017

3) Modification of the waveguide network under way, using SOLEIL Magic Switches

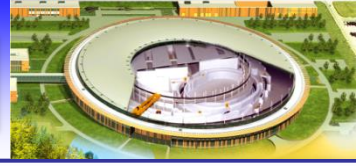
→ **In 2018, (1) + (2) + (3) → Possible operation @ 450 mA with**
- 3 running amplifiers or cavities ;
- a single cryomodule (combining 2 amplifiers per cavity).

4) 2nd Booster RF station (spare RF cavity, new 60 kW SSPA, LLRF & control)
→ Doubling of the injection efficiency in low-α mode
→ Cavity under conditioning in our test area, using the new 60 kW SSPA
→ Commissioning beginning of 2018

OTHER PROJECTS

- **The 4 SSPA's supplied to SESAME are in operation in their SR**
  - The 1st one was built by SOLEIL as a demonstrator,
  - The 3 other ones were built on the same model by SigmaPhi Electronics, the SOLEIL licensee
- **Installation & commissioning of the ThomX LINAC and SR RF system** → 2017 - 2018
- **LUCRECE / LUNEX5 : R&D about RF technology for CW LINAC (2016 – 2020)**
  → 20 kW 1.3 GHz SSPA using GaN instead of LDMOS transistors & LCLS2 type cavity
- **Upgrade of SOLEIL towards a DLSR** → Longitudinal kick for on-axis injection + harmonic system

Toward storing 500 mA using a single CM



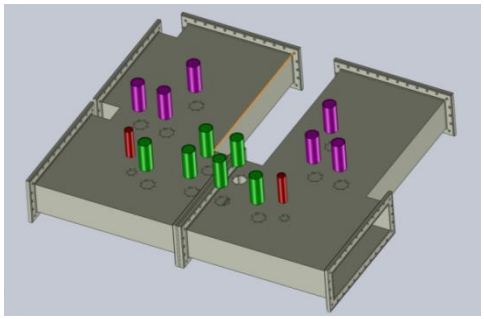
Together with the SSPA refurbishment,

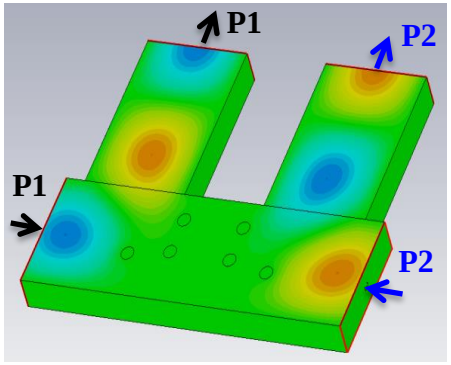
1) Design and implement the new version of cavity power couplers : 200 kW → 300 kW / cavity

2) Modify the waveguide network to combine the power from two amplifiers into one cavity

→ Possibility of storing the full beam current using a single CM or 3 running cavities

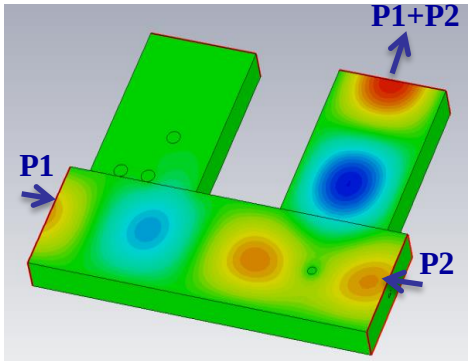
« Magic Switch »

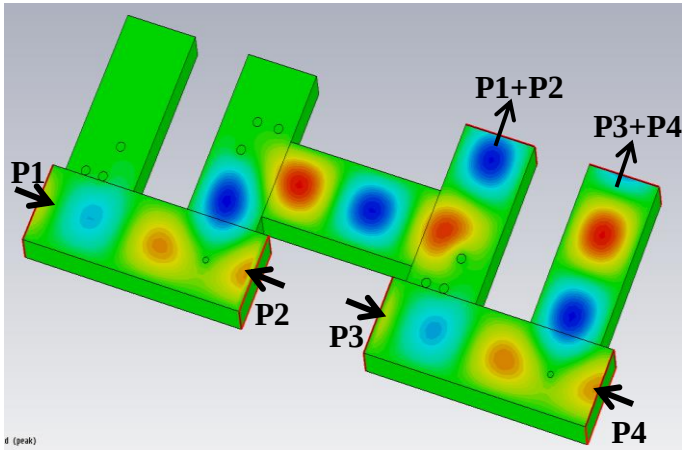




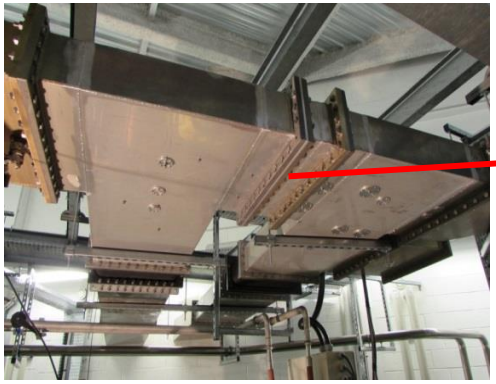
OR

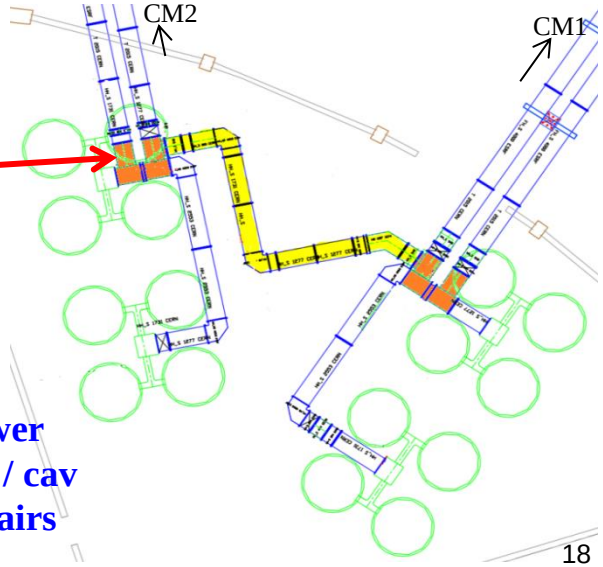
Depending on the post configuration





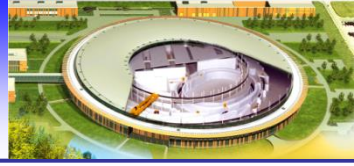
Connecting 2 Magic Switches





Wave guide network layout to power one or the other CM with 300 kW / cav from the 4 SSPA's, combined by pairs

Booster RF upgrade plan



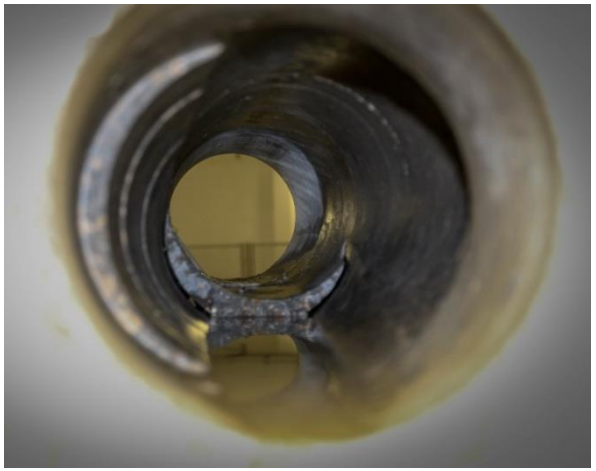
Presently the SSPA is powering one 5-cell copper cavity which provides a V_{RF} of 1 MV
Standard operation : P_{diss} (V_{RF} = 1 MV) = 20 kW ; P_{beam} = 5 kW → P_{tot} = 25 kW

Upgrade plan : Increase V_{RF} *from 1 MV up to 3 MV* to achieve shorter bunch length with the objective of *improving the SR injection efficiency in low-α operation mode* by a factor of ~ 2 (presently limited by radiation safety reasons)

- **Install our available spare cavity in the Bo ring** and power it with 60 kW (V_{RF} = 1.8 MV)
- → **Build a new 60 kW - 352 MHz SSPA, identical to a standard tower of our SR amplifiers**
  10 dissipaters of 16 modules, using the 160 RF modules of 400 W with BLF574 transistors and their dc-dc converters, got back from the upgrade of these amplifiers
- **Increase V_{RF} of the existing plant from 1 MV up to 1.2 MV** → P_{RF} ~ 30 kW (P_{beam} ~ 0)
- There is space for the 2nd cavity in one straight section of the ring and for the SSPA with its LLRF & control (replica of the actual one) inside the Bo RF room → **Infrastructure work**
- **Additional benefits** : power savings & redundancy in all the other modes of operation

Project status : 60 kW SSPA completed → Cavity conditioning in test area in Nov. 2017
Infrastructure work ongoing → Installation & commissioning scheduled for early 2018

Booster preparation work for installing a second RF cavity



Hole in the shielded BOO wall

New 30°C cooling circuit

Only the cavity is missing

Double V-Low beta SS (long BLs)

Monitoring alignment both IDs and photon absorber
Double XBPM + new imager

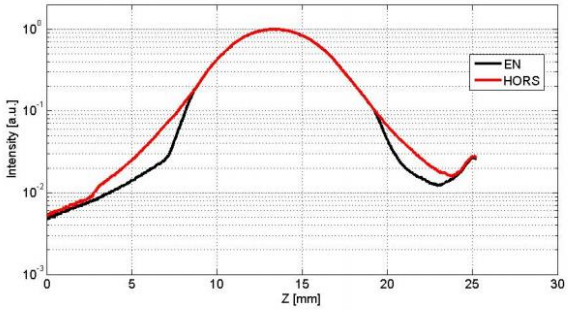
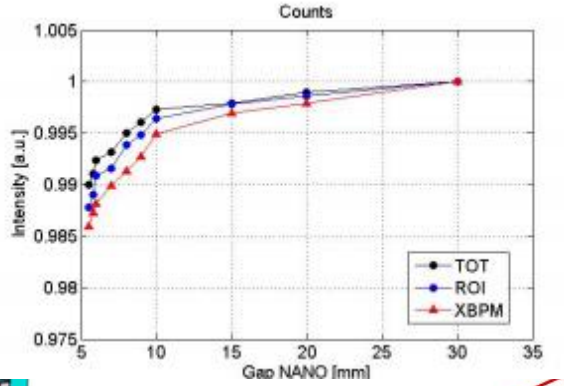


FIGURE 14 – Imager image with ABS HORS and EN. I=1
Data 25/08/2017.

CVD
6 mA max
MSS

Courtesy of M. Labat



Photon absorber

Installed and commissioned in August 2017

Vertical beam size stability

❑ Global Feedback system:

2012: First operation, handling the variation of 32 skew quadrupoles (SQ) field and the monitoring of vertical beam size by means of a pinhole camera [scaling of a vertical dispersion wave every 3 seconds].

2017:

- **Redundancy of the feedback** on the second pinhole camera

- **First successful test to change the actuator**.
  - ❑ Goal:
  - Increase repetition rate of the global feedback
  - Avoid crossed talk of SQ field with machine skew gradient defaults.
  - ❑ Means:
  - The Transverse Feedback System should replace the SQ thanks to the modulation of a white noise.

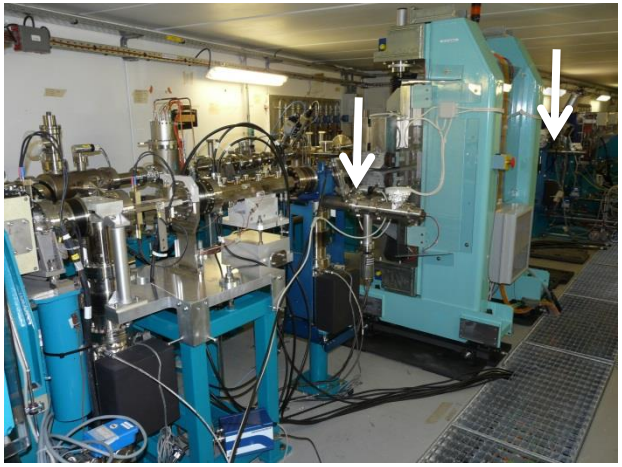
Coupling Feedback System interface

Vertical beam size stability

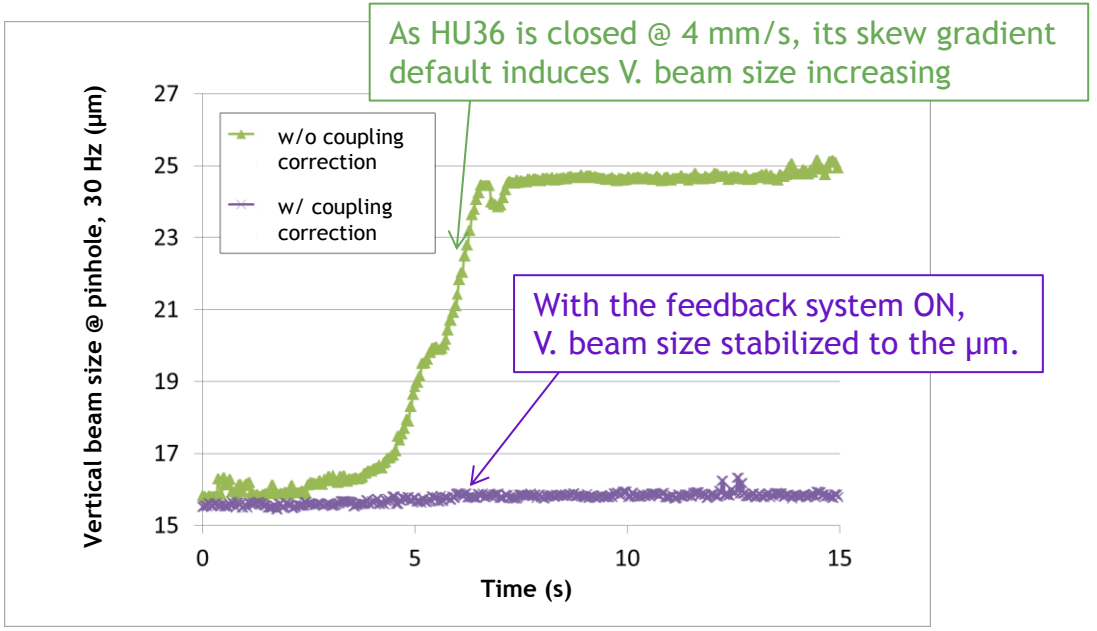
❑ Local feedforward system (1 system for 1 undulator)

to be installed on the 2 IDs that perturb the electron beam beyond specifications (+/-2 % on beam sizes for 8 hours).

- **2016:** First system for HU36, with gap varying @ 4 mm/s. Effective frequency around 60 Hz [Profibus]
- **2017:** On-going correction for the 10 m long electromagnetic HU640 [analog control to follow fast switching of the main field @ 1500 A/s]



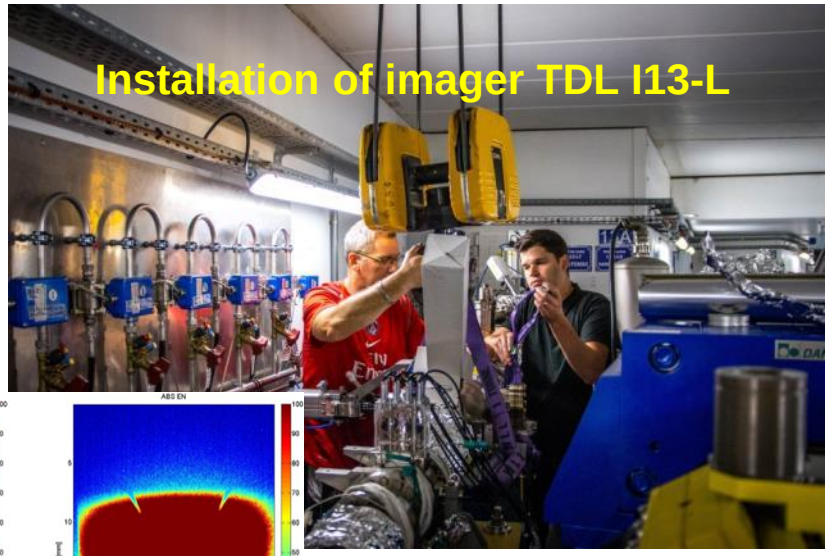
Installation of 2 new in air skew quadrupole correctors around the undulator HU36 and its command control 60 Hz.

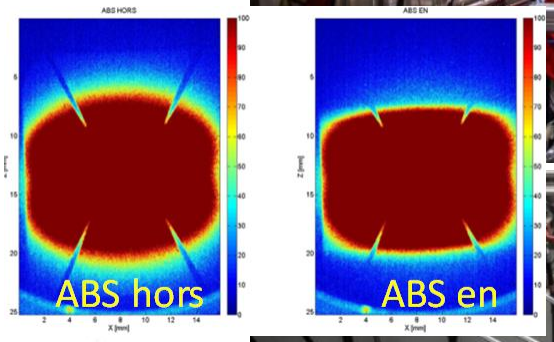


Test of the new coupling feedforward system, applied to the fast varying HU36 undulator.

Coupling control

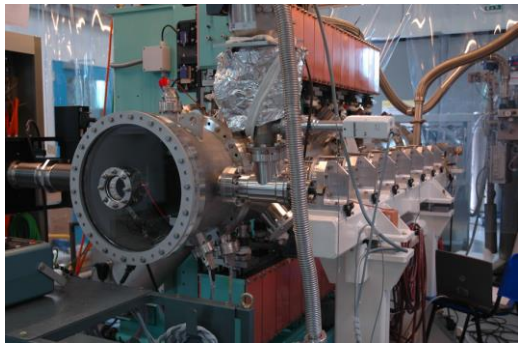
- ID induced control
- Slow coupling FFWD for a Apple-II commissioned
- Slow coupling for HU640 ID





New fast skew quadrupole corrector of H640 coupling --- FFWD under commissioning

Cryogenic undulator developments at SOLEIL



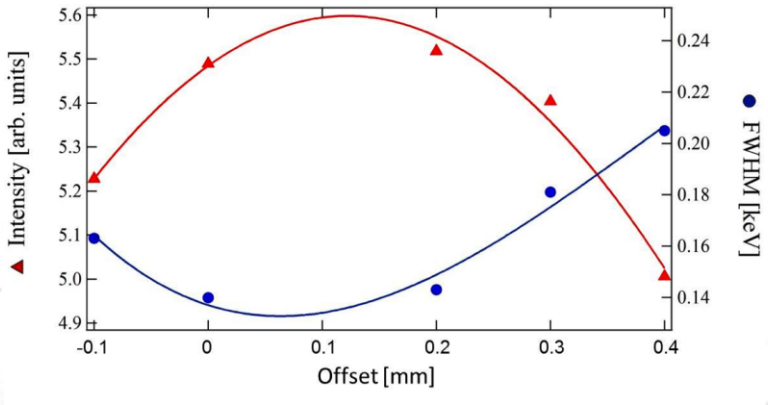
First PrFeB cryogenic undulator built at SOLEIL:
U18 CPMU n°1 (2 m long) installed on Nanoscopium beamline

C. Benabderrahmane et al, Nucl. Instr. Meth. A A 669 (2012) 1-6

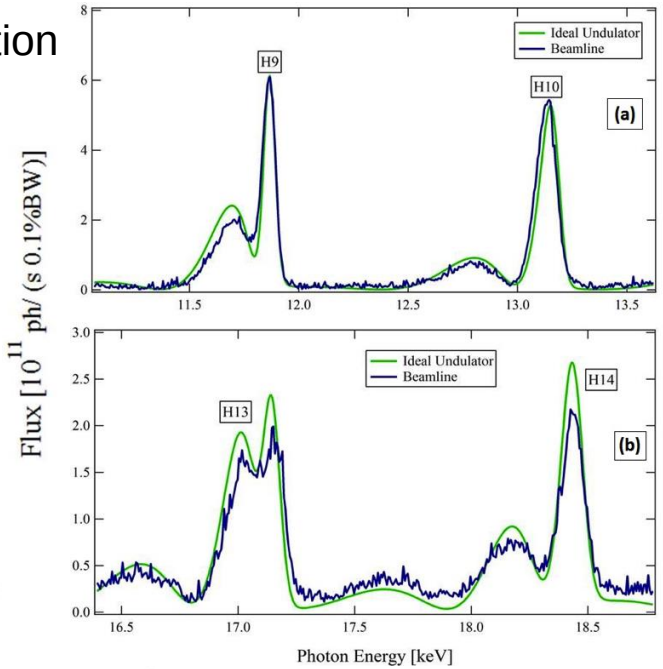
$Nd_2Fe_{14}B$ and $Pr_2Fe_{14}B$ magnets characterisation and modelling for cryogenic permanent magnet undulator applications, C. Benabderrahmane, P. Berteaud, M. Valléau, C. Kitegi, K. Tavakoli, N. Béchu, A. Mary, J. M. Filhol, M. E. Couprie, *Nuclear Instruments and Methods in Physics research A 669 (2012) 1-6*

Photon beam characterization

Photon beam-based alignment



→ *U18 offset adjusted by 100 μm*

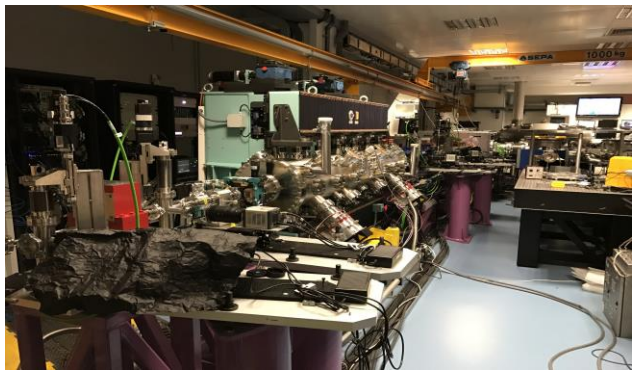


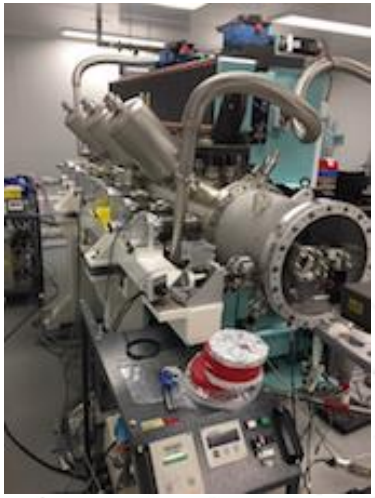
Measured spectra compared with simulation of an ideal undulator

Cryogenic undulator developments at SOLEIL

Second PrFeB cryogenic undulator built at SOLEIL:
U18 CPMU n°2, 2 m long, with half poles

Installed on COXINEL test experiment
(→ A. Loulergue's presentation tomorrow)



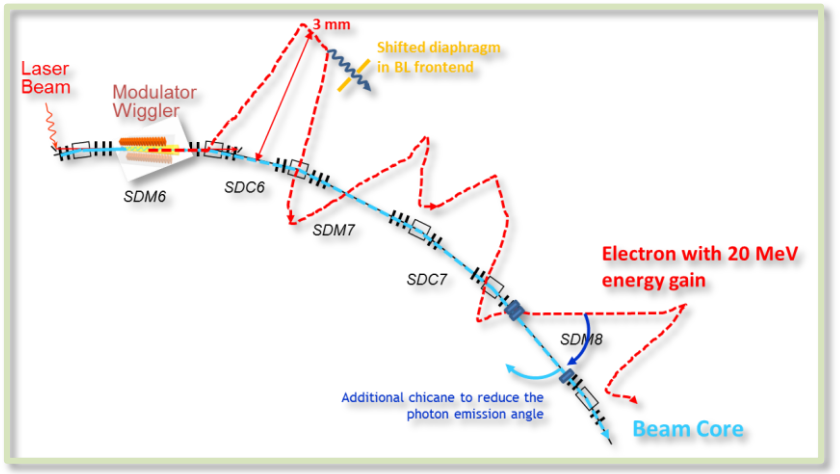


Third PrFeB cryogenic undulator built at SOLEIL:
U18 CPMU n°3, 2 m long

To be installed on Anatomix Beamline Dec 2017
Phase error at 77 K below 3°

U15 PrFeB 3 m cryogenic undulator prototype
(SOLEIL / MAX IV collaboration)
Measured modules

Femtoslicing progress



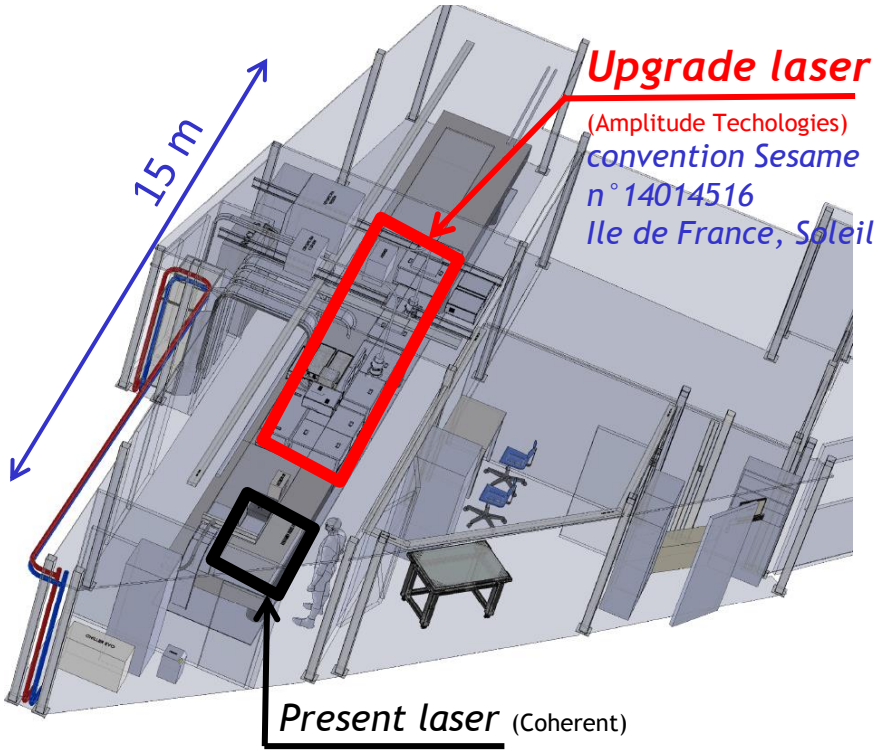
- Five weeks of operation from June 2016 to Feb. 2017

- Since Feb. 2017, Upgrade of the laser:
  - Shutdown of the femto-slicing operation
  - Present laser: 25 fs, 5 mJ/pulse @ 1 kHz
  - **+ Upgrade laser: 40 fs**
    6.5 mJ/pulse @ 5 kHz
    5 mJ/pulse @ 8 kHz
    4 mJ/pulse @ 10 kHz

  - ✓ Factory Acceptance test mid April 2018
  - ✓ Site Acceptance test Autumn 2018
  - ✓ Commissioning with the upgrade laser Spring 2019

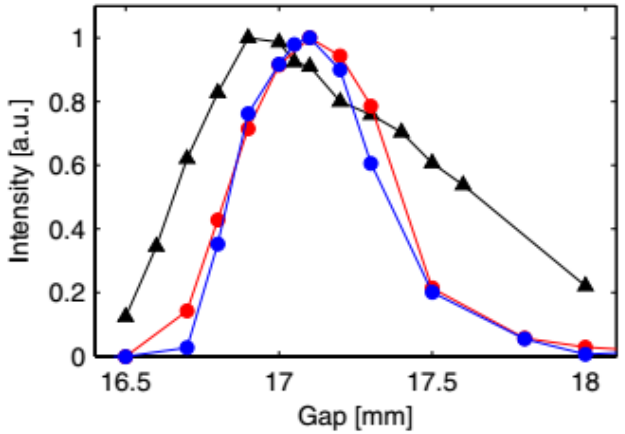
- Installation of a THz diagnostic in the SR tunnel in August 2018

- Operation resumption with external users foreseen in Call for Proposal #2 2019



Femto-slicing operation

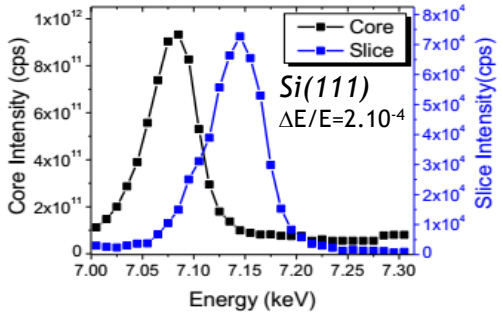
- For the first time in a Femto-slicing scheme, two beamlines are simultaneously benefiting from sub-ps pulses



- ▲ *THz intensity on AILES beamline*
- ● *Slice photon flux on CRISTAL beamline*
- ● *Slice photon flux on TEMPO beamline*

Simultaneous record of 3 signals versus the gap of the wiggler modulator: from bolometer on the THz beamline, and from detector on hard and soft X-ray beamlines.

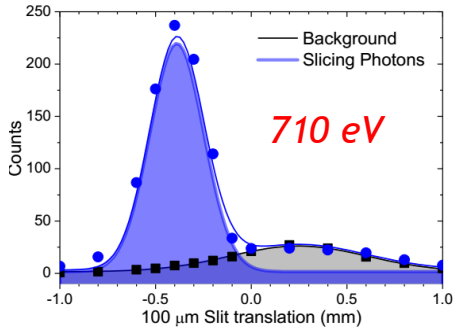
Hard X-ray beamline CRISTAL



Energy separation of core and slicing photons (7.1 keV).

- ✓ Evidence of photon **short bunch length < 140 fs FWHM** @ CRISTAL
- ✓ Setting up of a new multilayer monochromator Ni/B_4C **→ Flux : 1000 ph/pulse in ΔE/E=1%**

Soft X-ray beamline TEMPO



Spatial separation of core and slicing photons.

- ✓ First photons measured @ TEMPO in December 2016.

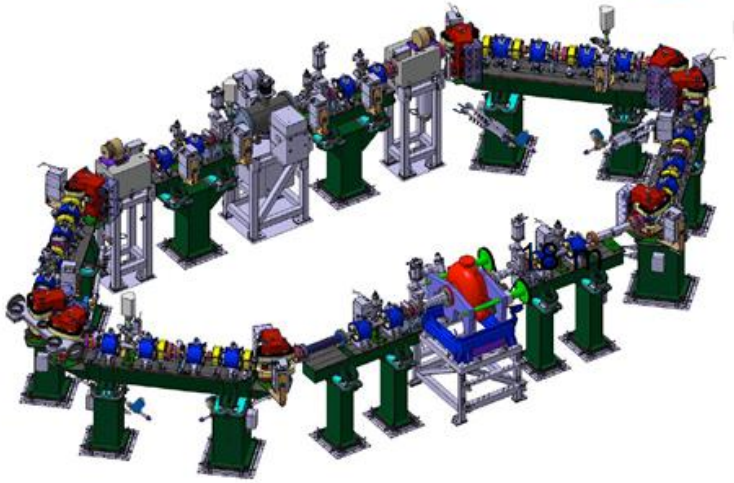
THOMX

Compton Back Scatering X-ray source

Electron : 1 bunch, 1 nC, 20 to 70 MeV max
Rep = 20 MHz in a ring

Laser : 1 pulse, 10 – 30 mJ max
Rep = 40 MHz in FP cavity

X-Flux : up to 90 keV
up to 10^{13} Photon/s



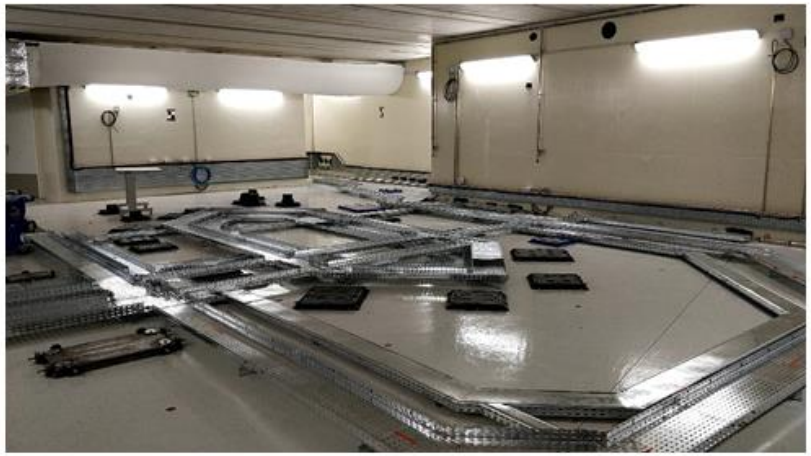
Status

All installation should end by mid-2018

Commissionning start mid-2018
Linac then Ring

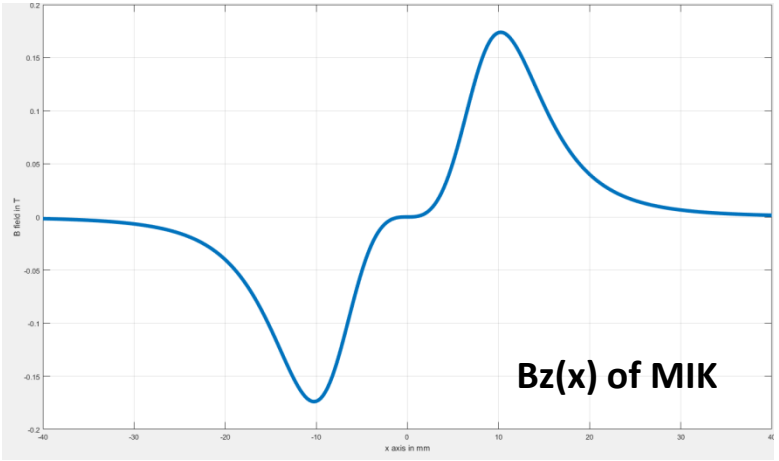
First photon by end of 2018

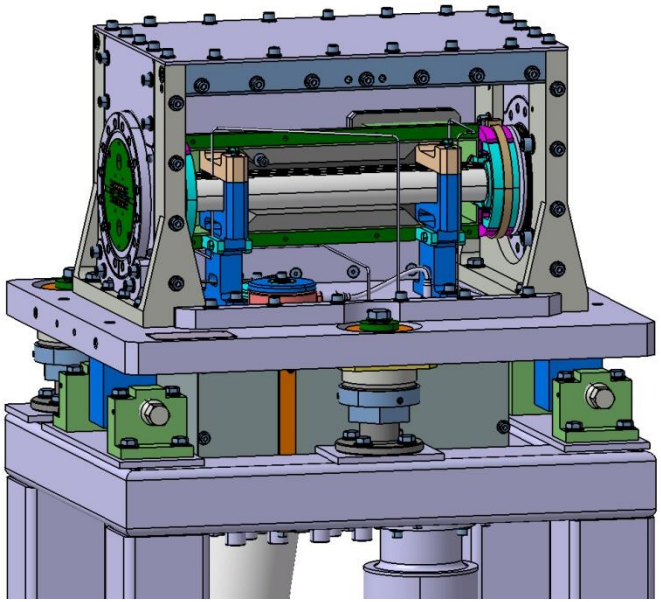
Installation started
from August 2017



MAX-IV – SOLEIL Multipole Injection Kicker (MIK) project
Summarized overview

- **A single short magnet (400 mm) that allows transparent Top-Up injection** in the next generation of storage rings, in lieu of traditional 4 kicker bump injection scheme.
- **Aim of project is to design and build such magnets and its pulsed power supplies** for MAX-IV 3 GeV ring and SOLEIL 2.75 GeV ring. Budget : 774 k€.
- **For MAX-IV 3 GeV ring: integrated field of deflection is 11.7 mTm (ie 1.17 mrad).** Peak current in magnet coils : 7700 A under 14 kV.
- **The final design is inspired from the octupole-like non linear kicker of Bessy II, with the main points:**
    - Vacuum chamber is made of pure monocrystalline sapphire with internal 1 µm titanium coating.
    - Magnet coils are embedded in the sapphire chamber which requires extremely tight machining tolerances to achieve excellent quality of the zero field region at center.
    - High voltage on very compact magnet led to detailed engineering of insulators.
    - Extensive work on the pulsed power supplies to minimize voltage constraints on magnet while delivering fast current pulses.

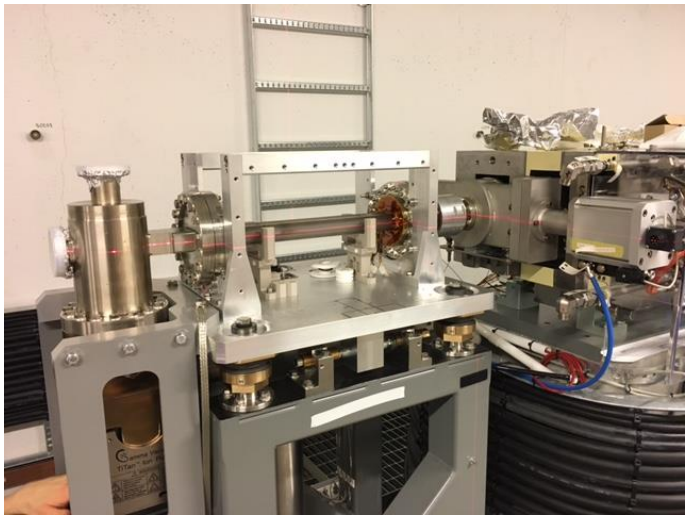




3D view of the complete MIK magnet

MAX-IV – SOLEIL Multipole Injection Kicker (MIK) project
Timeline : 2012 – 2017/18

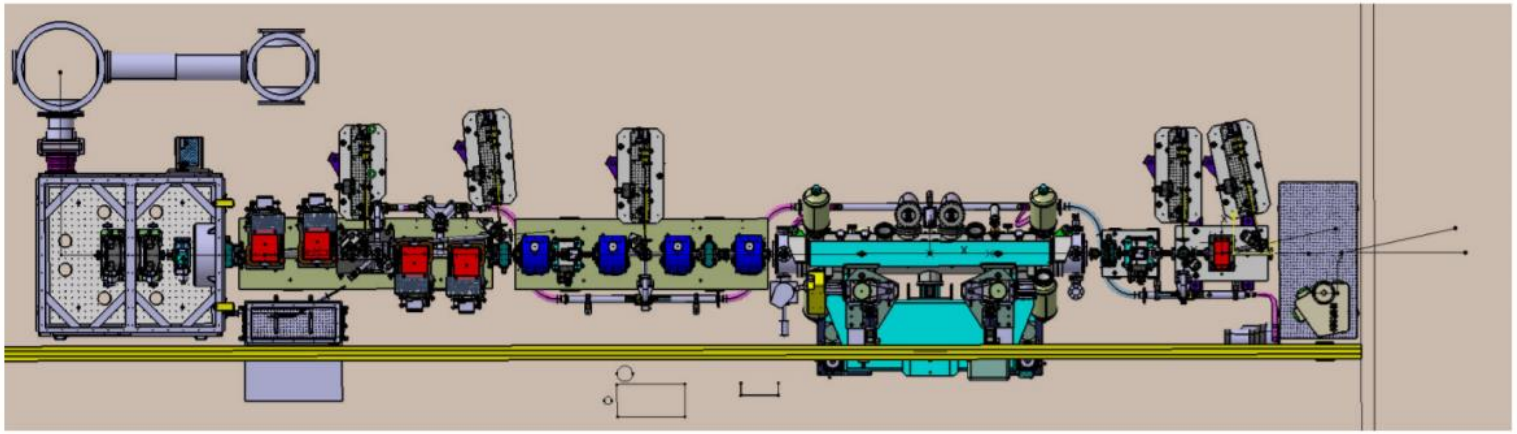
- **Early 2012 - Mid 2014:** Preliminary designs of MIK magnets and high voltage pulsed power supplies to meet the extensive specifications of both machines. Prototyping on feasibility of embedded conductors in vacuum chamber.
- **Mid 2014 - April 2015:** Detailed designs of all subsystems (magnet & vacuum chamber, mechanics, pulser, control system, high voltage power supplies, etc..). ***Numerous call for tenders followed.***
- **May 2015 – Dec. 2016:** delivery of all subcomponents required to build a first compete system (vacuum chamber with magnet, mechanics, pulser, controls cabinets).
- **2017: assembly of a first complete prototype of MIK magnet.** The assembly of the magnets & other subcomponents is done at SOLEIL by skilled technicians.
- **July 2017:** magnetic measurement of the prototype magnet, after complete electrical testing.
- **August 2017:** installation on MAX-IV 3 GeV ring of a complete MIK system. **Commissioning with beam should happen in Dec. 2017 and early 2018**.
- **2018:** end of assembly of 4 definitive MIK magnets and installation on MAX-IV & SOLEIL rings for routine operation.



MIK magnet installed on 3 GeV ring at MAX-IV

MIK pulsed power supply, control cabinets and high voltage charging power supplies at MAX-IV.

Project COXINEL:
FEL amplification using Laser Plasma Acceleration



Goals :

- Demonstrate an appropriate transport to the undulator, and FEL amplification at 200 nm and later at 40 nm using undulators from SOLEIL
- Investigate and control (theory/experiments) FEL performance

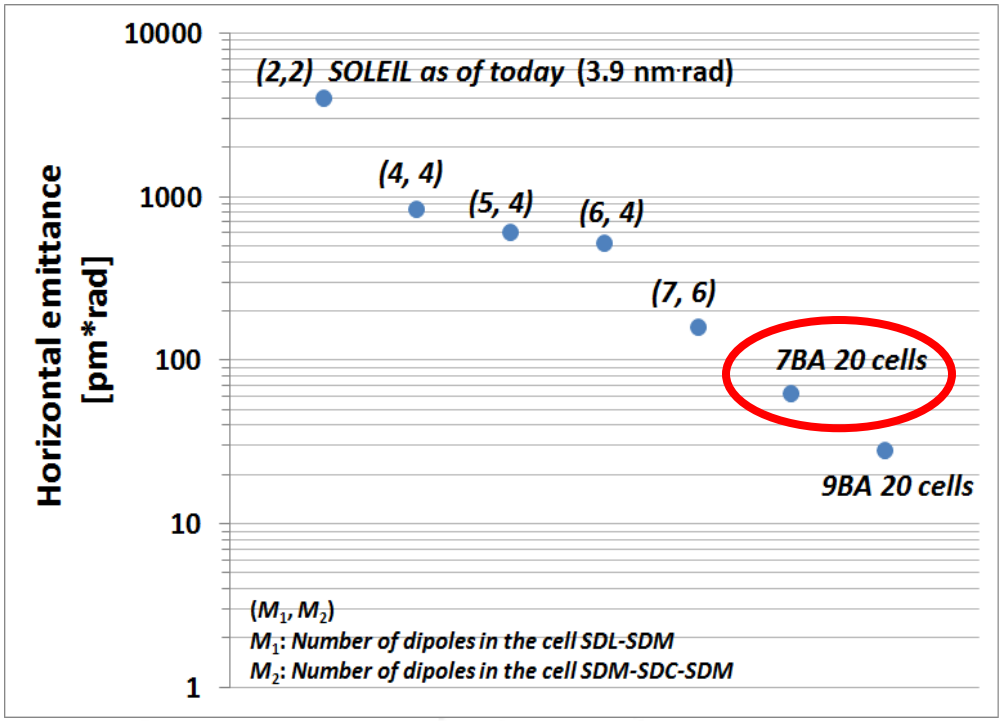
M. E. Couprie et al. J. Physics B : At., Mol. Opt. Phys. (2014) 234001
A. Loulergue et al.., New J. Phys. 17 (2015) 023028 (2015)
M. E. Couprie et al., Plasma Physics and Controlled Fusion, Volume 58, Number 3 (2016)

⇒ A dedicated talk by A. Loulergue (SOLEIL) tomorrow

Upgrade SOLEIL

Dramatically enhanced photon beam brilliance and coherent flux to beamline experiments as compared to the present machine are aimed by respecting the following conditions:

- Reduce by more than a factor 30 or 40 the horizontal electron beam emittance (in the order of 100 pm.rad).
- Reuse of the existing tunnel and its radiation shielding wall.
- Maintain the existing insertion device source points.
- Keep a storage ring energy that covers a very broad photon energy range.
- Preserve a current of 500 mA in multibunch operation.
- Preserve time structure and time resolved operations.
- Reuse of the injector complex: linac and booster.
- Reuse much of the technical infrastructure.
- Limit downtime to a maximum of two years.
- Minimize operation costs, in particular the wall-plug-power.
- Preserve Infra-Red (IR) beamlines.
- Provide alternative radiation sources for the existing bending magnet based beamlines.



Evolution of lattice studies carried out for the SOLEIL upgrade

⇩

An optimized solution having 7BA 20 cells defined as the ***baseline lattice***

⇒ **Dedicated talks on**

- **Lattice studies, by A. Loulergue**
- **Studies of longitudinal on-axis injection scheme, by myself tomorrow**

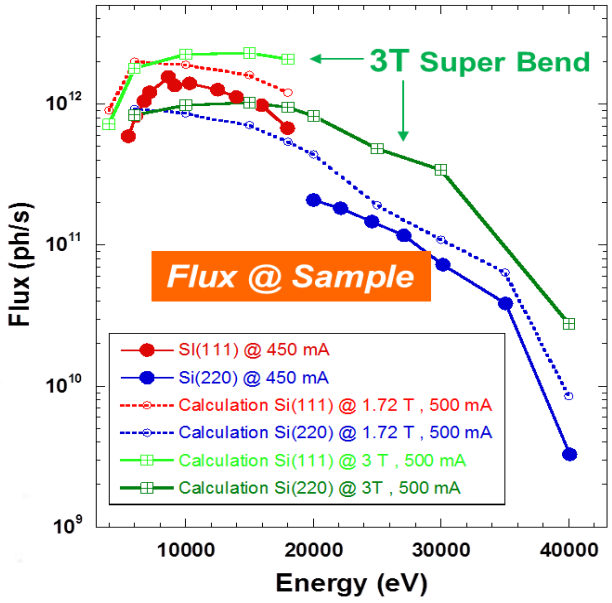
2018 roadmap (1)

- Installation new cryogenic U18 in double V low-beta SS
  - Both long BLs to receive users by end of July (2x 5.5 mm IVUs)
  - New 4 magnet chicane (reliability, redundancy)
- Femtosecond upgrade
  - Building a THz Beamline (SR tunnel)
    - Diagnostics for maintaining Femtoslicing interaction (Sem2 2018)
  - New laser for both Soft and hard X-ray BLs
- Continuous improvement for the operation
  - Spare power supplies for SR sextupole PS and dipole LT2
  - Operating at 500 mA with a single cryomodule, and degraded modes for user beam.
  - Upgrade TFB (SPring-8 processor)
  - Fast coupling FWD for a mechanical and a fast switch electromagnetic IDs

2018 roadmap (2)

- Installation of second 5 cell Cu cavity in Booster
  - Low-alpha mode:
    - Possibility to increase injection efficiency from 15-20% to 30-35% by shortening BOO bunches
    - Open the possibility to increase the number of BLs in this mode by overcoming the radiation safety limitation
  - Redundancy for user operation

- Project study for replacing a 1.71 T bending dipole with a super)-bend of 3T
  - Increasing flux in 14-43 keV domain
  - Choice of technology (electromagnet or Permanent Magnet)



2018 Beam Calendar