SOLEIL Status and Upgrade Strategy for a DLSR

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On behalf of the Accelerators and Engineering Division

Layout of the presentation

- SOLEIL Metrics
- Achievements
- On-going Projects
- Upgrade Plans for a DLSR
- Roadmap for 2019

Lattice

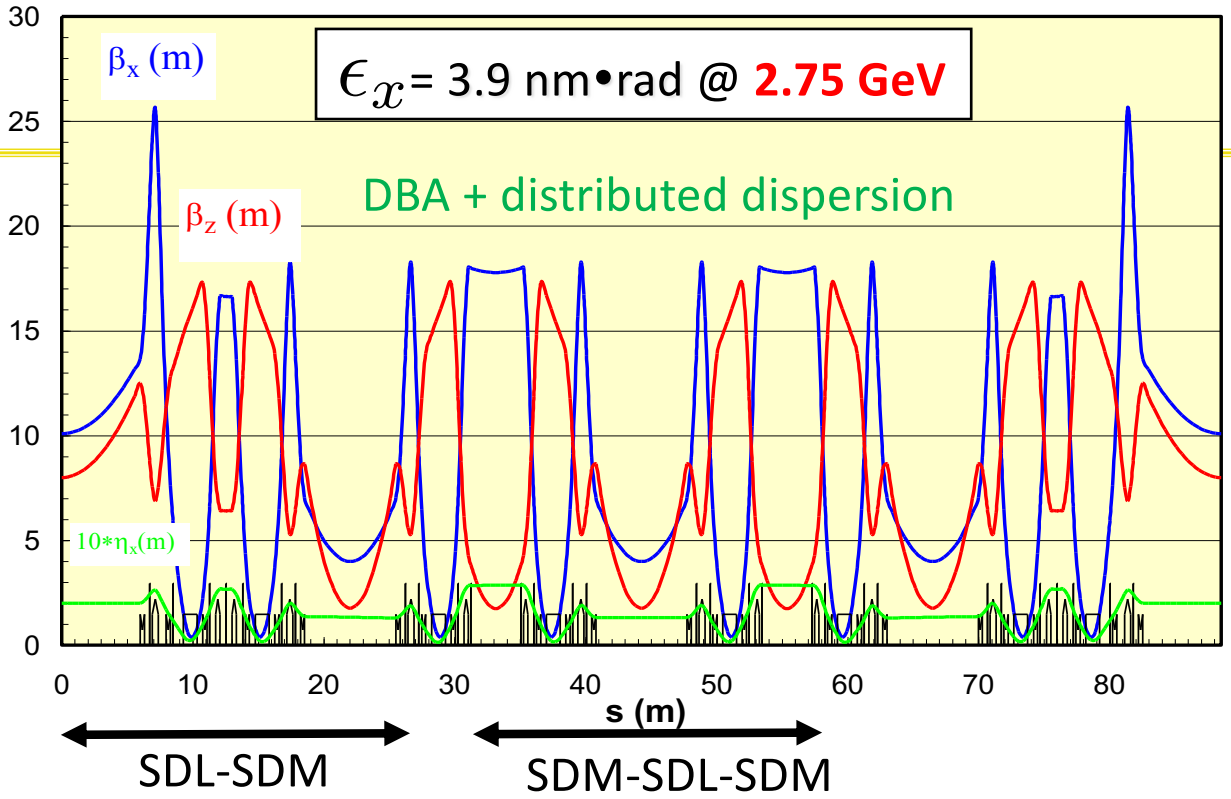
Location: France

Circumference: **354 m**

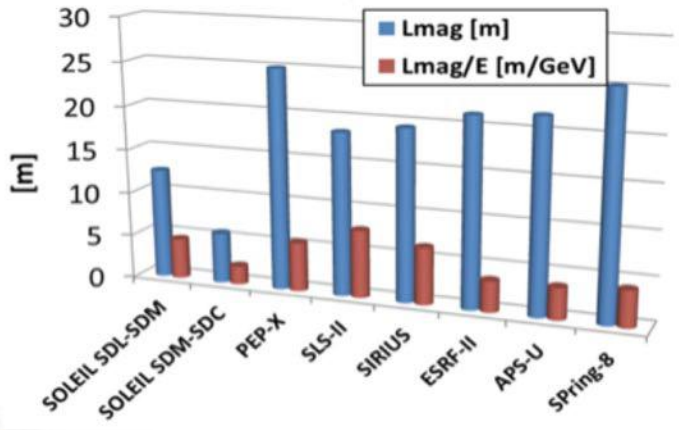
24 straight sections

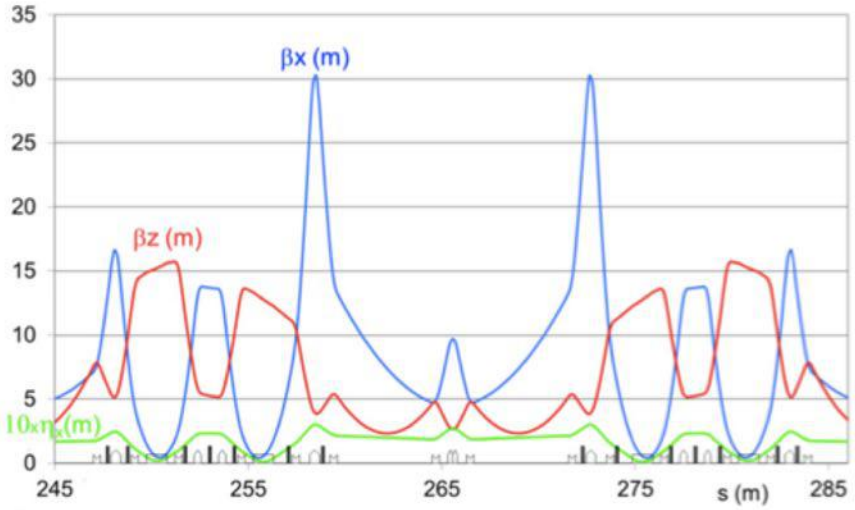
(variable length)

SDC: 4 x 12 m
SDM: 12 x 7 m
SDL: 8 x 3.6 m



Very compact magnetic structure





One long straight section (SDL13, accommodating 2 canted long beamlines) has been modified

Beam Time Schedule in 2018

5019 hours for the beamlines

janv 2018				févr 2018				mars 2018				avr 2018				mai 2018				juin 2018				juil 2018				août 2018				sept 2018				oct 2018				nov 2018				déc 2018			
lun 01	.	.	.	jeu 01	H	H	H	jeu 01	.	.	.	dim 01	U	U	U	mar 01	.	.	.	ven 01	U	U	U	dim 01	H	H	H	mer 01	.	.	.	sam 01	A	A	A	lun 01	A	A	Tv	jeu 01	S	S	S	sam 01	H	H	H
mar 02	.	.	.	ven 02	H	H	H	ven 02	.	.	.	lun 02	A	A	A	mer 02	.	.	.	sam 02	U	U	U	lun 02	A	A	A	jeu 02	.	.	.	dim 02	A	A	A	mar 02	B	B	B	ven 02	S	S	S	dim 02	H	H	H
mer 03	.	.	.	sam 03	H	H	H	sam 03	.	.	.	mar 03	B	B	B	jeu 03	.	.	.	dim 03	U	U	U	mar 03	Cp	Cp	B	ven 03	.	.	.	lun 03	A	A	A	mer 03	H	H	H	sam 03	S	S	S	lun 03	A	A	Tv
jeu 04	.	.	.	dim 04	H	H	H	dim 04	.	.	.	mer 04	H	H	H	ven 04	.	.	.	lun 04	A	A	Tv	mer 04	U	U	U	sam 04	.	.	.	mar 04	B	B	B	jeu 04	H	H	H	dim 04	S	S	S	mar 04	B	B	B
ven 05	.	.	.	lun 05	A	A	Tv	lun 05	.	.	.	jeu 05	H	H	H	sam 05	.	.	.	mar 05	B	B	B	jeu 05	U	U	U	dim 05	.	.	.	mer 05	U	U	U	ven 05	H	H	H	lun 05	A	A	Tv	mer 05	H	H	H
sam 06	.	.	.	mar 06	B	B	B	mar 06	.	.	.	ven 06	H	H	H	dim 06	.	.	.	mer 06	U	U	U	ven 06	U	U	U	lun 06	.	.	.	jeu 06	U	U	U	sam 06	H	H	H	mar 06	B	B	B	jeu 06	H	H	H
dim 07	.	.	.	mer 07	H	H	H	mer 07	.	.	.	sam 07	H	H	H	lun 07	.	.	.	jeu 07	U	U	U	sam 07	U	U	U	mar 07	.	.	.	ven 07	U	U	U	dim 07	H	H	H	mer 07	U	U	U	ven 07	H	H	H
lun 08	.	.	.	jeu 08	H	H	H	jeu 08	.	.	A	dim 08	H	H	H	mar 08	.	.	.	ven 08	U	U	U	dim 08	U	U	U	mer 08	.	.	.	sam 08	U	U	U	lun 08	A	A	A	jeu 08	U	U	U	sam 08	H	H	H
mar 09	.	.	.	ven 09	H	H	H	ven 09	A	A	A	lun 09	A	A	Tv	mer 09	.	.	A	sam 09	U	U	U	lun 09	A	A	Tv	jeu 09	.	.	.	dim 09	U	U	U	mar 09	A	A	A	ven 09	U	U	U	dim 09	H	H	H
mer 10	.	.	.	sam 10	H	H	H	sam 10	A	A	A	mar 10	B	B	B	jeu 10	A	A	A	dim 10	U	U	U	mar 10	B	B	B	ven 10	.	.	.	lun 10	A	A	Tv	mer 10	L	L	L	sam 10	U	U	U	lun 10	A	A	Tv
jeu 11	.	.	.	dim 11	H	H	H	dim 11	A	A	A	mer 11	U	U	U	ven 11	A	A	A	lun 11	A	A	A	mer 11	U	U	U	sam 11	.	.	.	mar 11	8	8	8	jeu 11	L	L	L	dim 11	U	U	U	mar 11	B	B	B
ven 12	.	.	.	lun 12	A	A	Tv	lun 12	A	A	A	jeu 12	U	U	U	sam 12	A	A	A	mar 12	L	L	L	jeu 12	U	U	U	dim 12	.	.	.	mer 12	8	8	8	ven 12	L	L	L	lun 12	A	A	A	mer 12	U	U	U
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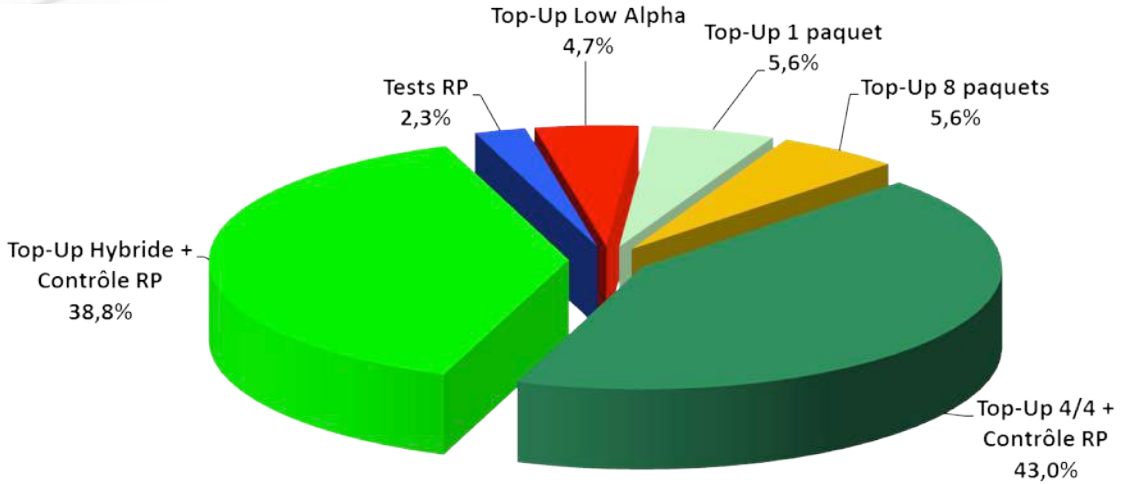
lun 15	.	.	.	jeu 15	U	U	U	jeu 15	H	H	H	dim 15	U	U	U	mar 15	S	S	S	ven 15	L	L	L	dim 15	U	U	U	mer 15	.	.	.	sam 15	8	8	8	lun 15	.	.	.	jeu 15	U	U	U	sam 15	U	U	U
mar 16	.	.	.	ven 16	U	U	U	ven 16	H	H	H	lun 16	A	A	Tv	mer 16	S	S	S	sam 16	L	L	L	lun 16	A	A	Tv	jeu 16	.	.	.	dim 16	8	8	8	mar 16	.	.	.	ven 16	U	U	U	dim 16	U	U	U
mer 17	.	.	A	sam 17	U	U	U	sam 17	H	H	H	mar 17	8	8	8	jeu 17	S	S	S	dim 17	Tv	Tv	A	mar 17	B	B	B	ven 17	.	.	.	lun 17	A	A	Tv	mer 17	.	.	.	sam 17	U	U	U	lun 17	U	U	U
jeu 18	A	A	A	dim 18	U	U	U	dim 18	H	H	H	mer 18	8	8	8	ven 18	S	S	S	lun 18	A	A	Tv	mer 18	H	H	H	sam 18	.	.	.	mar 18	B	B	B	jeu 18	.	.	.	dim 18	U	U	U	mar 18	U	U	U
ven 19	A	A	A	lun 19	A	A	Tv	lun 19	A	A	Tv	jeu 19	8	8	8	sam 19	S	S	S	mar 19	B	B	B	jeu 19	H	H	H	dim 19	.	.	.	mer 19	U	U	U	ven 19	.	.	.	lun 19	A	A	Tv	mer 19	U	U	U
sam 20	A	A	A	mar 20	B	B	B	mar 20	B	B	B	ven 20	8	8	8	dim 20	S	S	S	mer 20	H	H	H	ven 20	H	H	H	lun 20	.	.	.	jeu 20	U	U	U	sam 20	.	.	.	mar 20	B	B	B	jeu 20	.	.	.
dim 21	A	A	A	mer 21	U	U	U	mer 21	U	U	U	sam 21	8	8	8	lun 21	A	A	A	jeu 21	H	H	H	sam 21	H	H	H	mar 21	.	.	.	ven 21	U	U	U	dim 21	.	.	.	mer 21	H	H	H	ven 21	.	.	.
lun 22	A	A	A	jeu 22	U	U	U	jeu 22	U	U	U	dim 22	8	8	8	mar 22	B	B	B	ven 22	H	H	H	dim 22	H	H	H	mer 22	.	.	.	sam 22	U	U	U	lun 22	.	.	.	jeu 22	H	H	H	sam 22	.	.	.
mar 23	B	B	B	ven 23	U	U	U	ven 23	U	U	U	lun 23	.	.	.	mer 23	U	U	U	sam 23	H	H	H	lun 23	A	A	Tv	jeu 23	.	.	.	dim 23	U	U	U	mar 23	.	.	.	ven 23	H	H	H	dim 23	.	.	.
mer 24	H	H	H	sam 24	U	U	U	sam 24	U	U	U	mar 24	.	.	.	jeu 24	U	U	U	dim 24	H	H	H	mar 24	B	B	B	ven 24	.	.	.	lun 24	A	A	Tv	mer 24	.	.	.	sam 24	H	H	H	lun 24	.	.	.
jeu 25	H	H	H	dim 25	U	U	U	dim 25	U	U	U	mer 25	.	.	.	ven 25	U	U	U	lun 25	A	A	A	mer 25	H	H	H	sam 25	.	.	.	mar 25	B	B	B	jeu 25	.	.	A	dim 25	H	H	H	mar 25	.	.	.
ven 26	H	H	H	lun 26	.	.	.	lun 26	A	A	A	jeu 26	.	.	.	sam 26	U	U	U	mar 26	B	B	B	jeu 26	H	H	H	dim 26	.	.	.	mer 26	H	H	H	ven 26	A	A	A	lun 26	A	A	Tv	mer 26	.	.	.
sam 27	H	H	H	mar 27	.	.	.	mar 27	Cp	Cp	B	ven 27	.	.	.	dim 27	U	U	U	mer 27	H	H	H	ven 27	H	H	H	lun 27	.	.	.	jeu 27	H	H	H	sam 27	A	A	A	mar 27	B	B	B	jeu 27	.	.	.
dim 28	H	H	H	mer 28	.	.	.	mer 28	U	U	U	sam 28	.	.	.	lun 28	A	A	Tv	jeu 28	H	H	H	sam 28	H	H	H	mar 28	.	.	.	ven 28	H	H	H	dim 28	A	A	A	mer 28	H	H	H	ven 28	.	.	.
lun 29	A	A	Tv					jeu 29	U	U	U	dim 29	.	.	.	mar 29	B	B	B	ven 29	H	H	H	dim 29	H	H	H	mer 29	.	.	A	sam 29	H	H	H	lun 29	A	A	A	jeu 29	H	H	H	sam 29	.	.	.
mar 30	B	B	B					ven 30	U	U	U	lun 30	.	.	.	mer 30	U	U	U	sam 30	H	H	H	lun 30	.	.	.	jeu 30	A	A	A	dim 30	H	H	H	mar 30	S	S	S	ven 30	H	H	H	dim 30	.	.	.
mer 31	H	H	H					sam 31	U	U	U					jeu 31	U	U	U					mar 31	.	.	.	ven 31	A	A	A					mer 31	S	S	S					lun 31	.	.	.

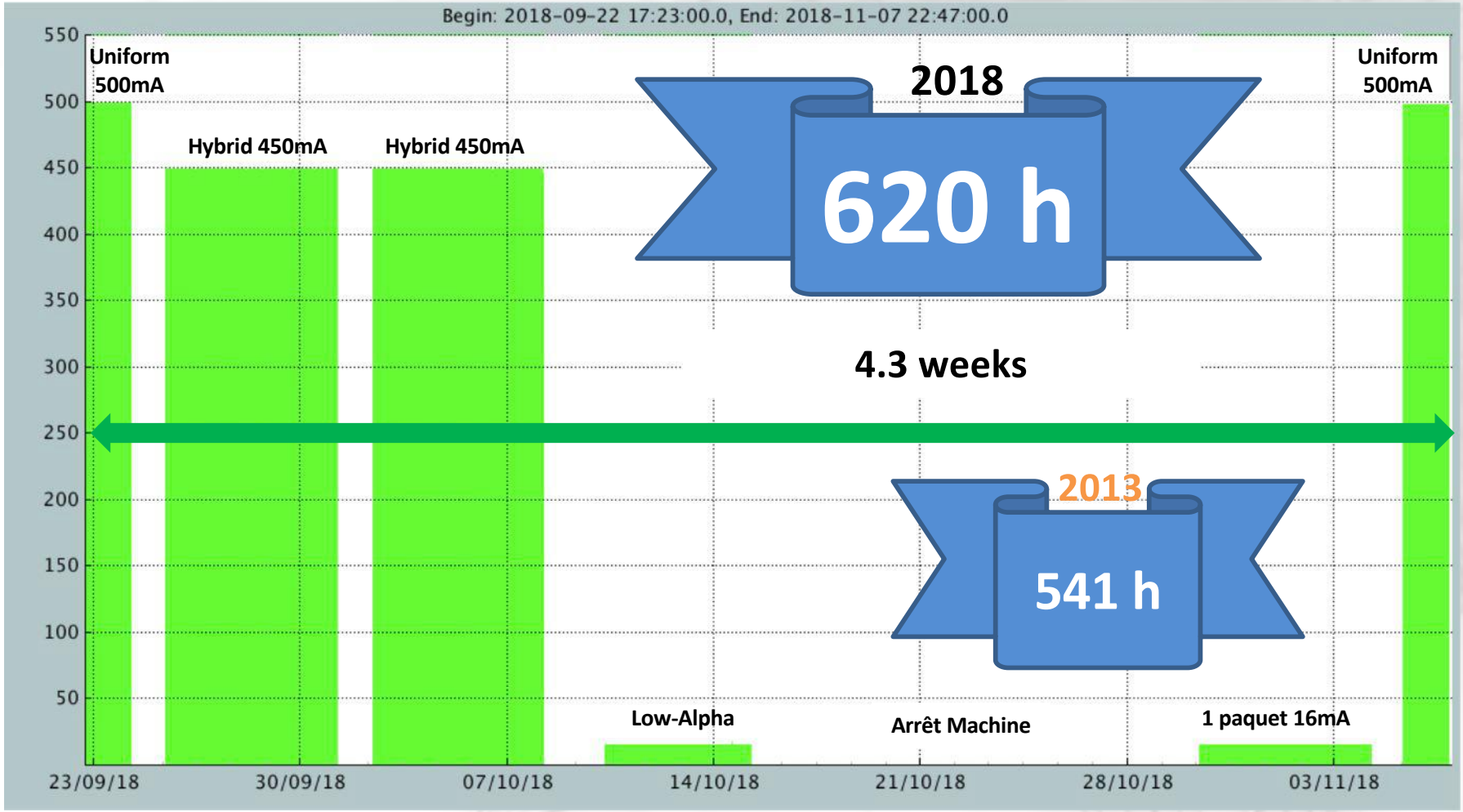
U	Uniform
H	Hybrid / camshaft
8	8 bunches
S	1 bunch
L	Low-Alpha
B	Beamlines
Cp	Periodic radiation safety checks
Tv	Radiation safety validation,
A	Accelerators
.	Shut down



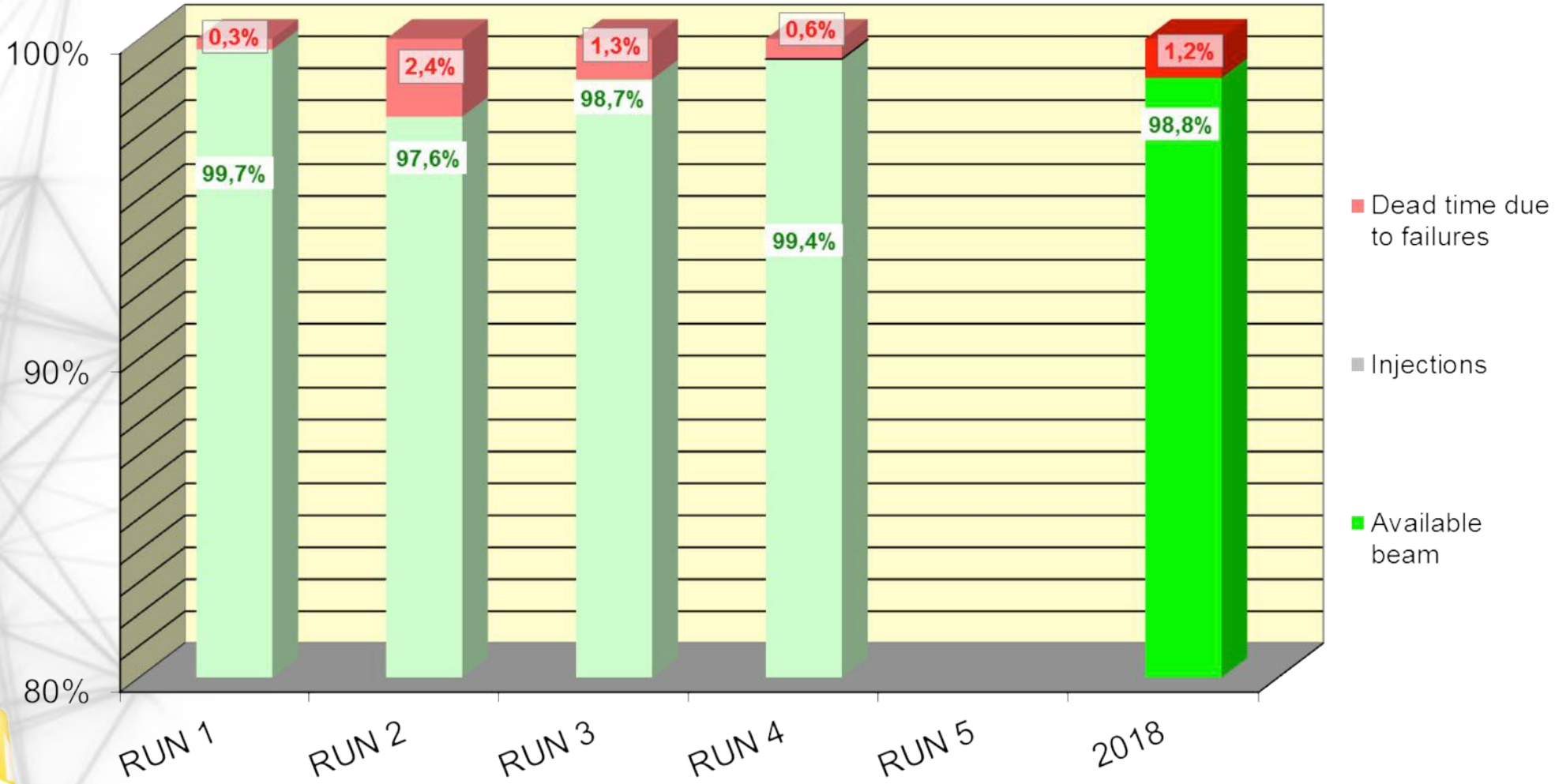
MTBF = 80 hours and MTTR = 0h58

Accumulated beam dose since commissioning > 20 000 A.h

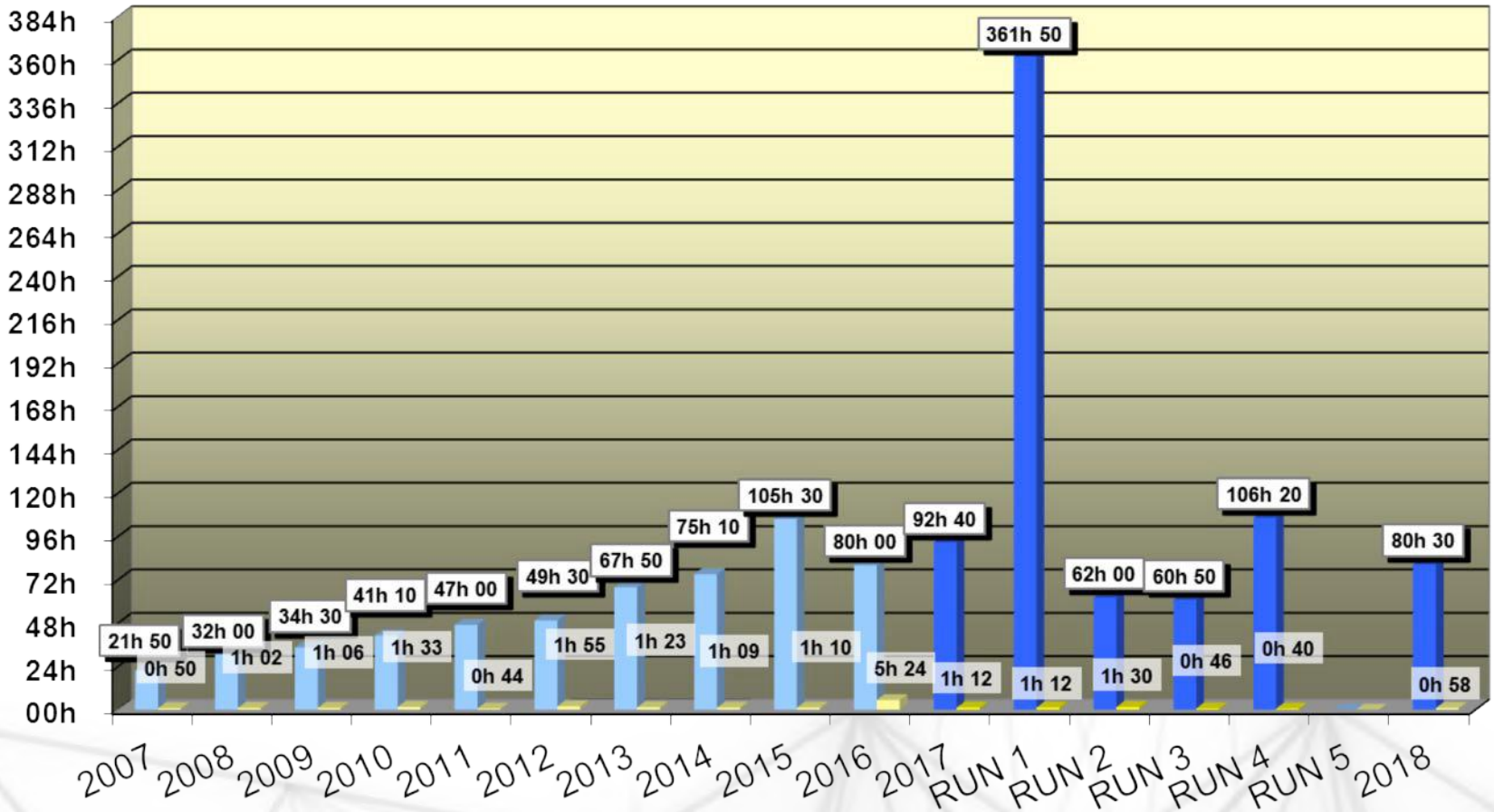
New Record for the longest uninterrupted beam for users



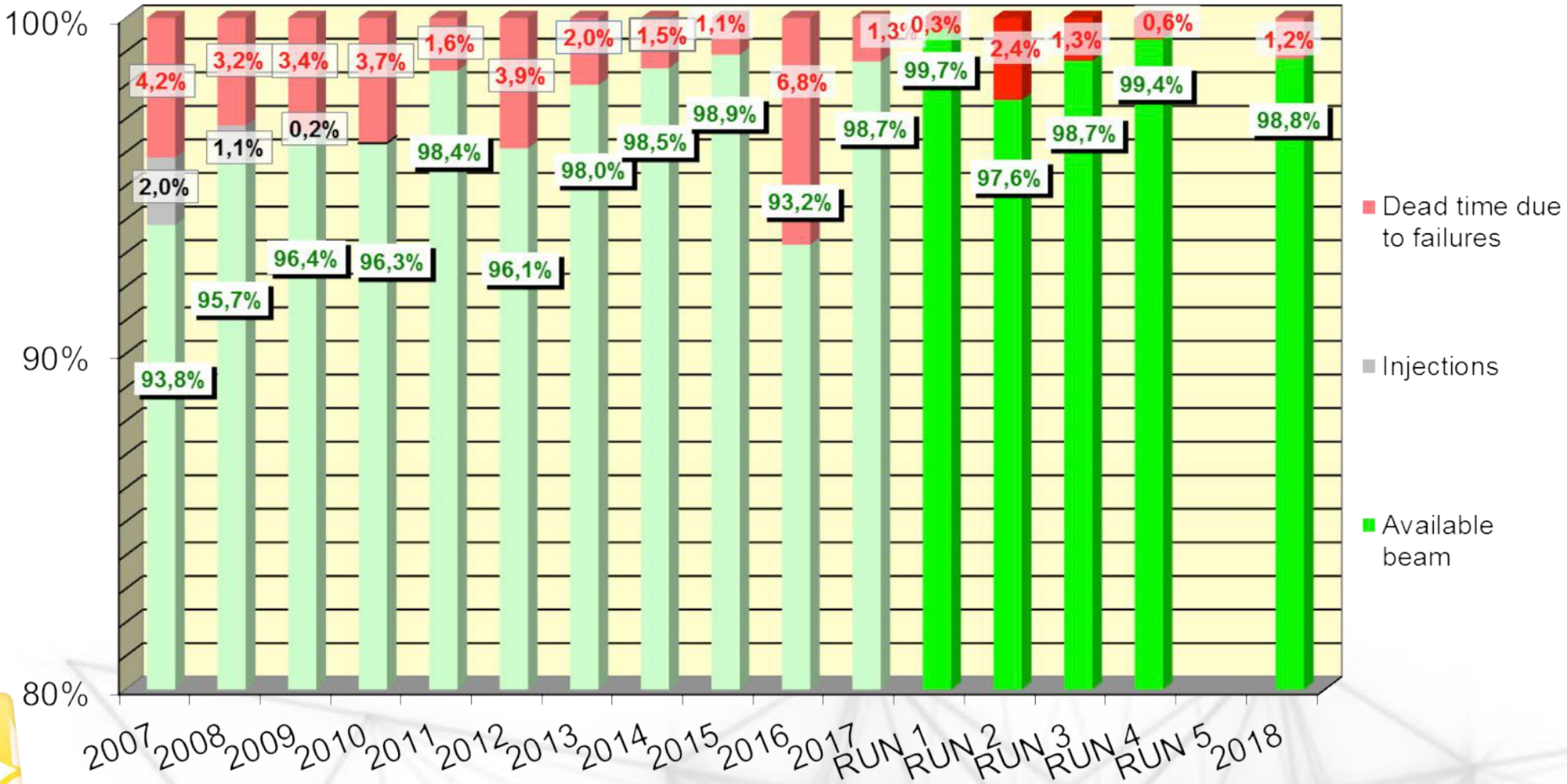
Photon Beam Availability (2018: Run1 to Run 4)



MTBF: Meantime between failures (80h30) and MTTR: MeanTime To Recovery (00h58) during beamlines and RP sessions in 2018



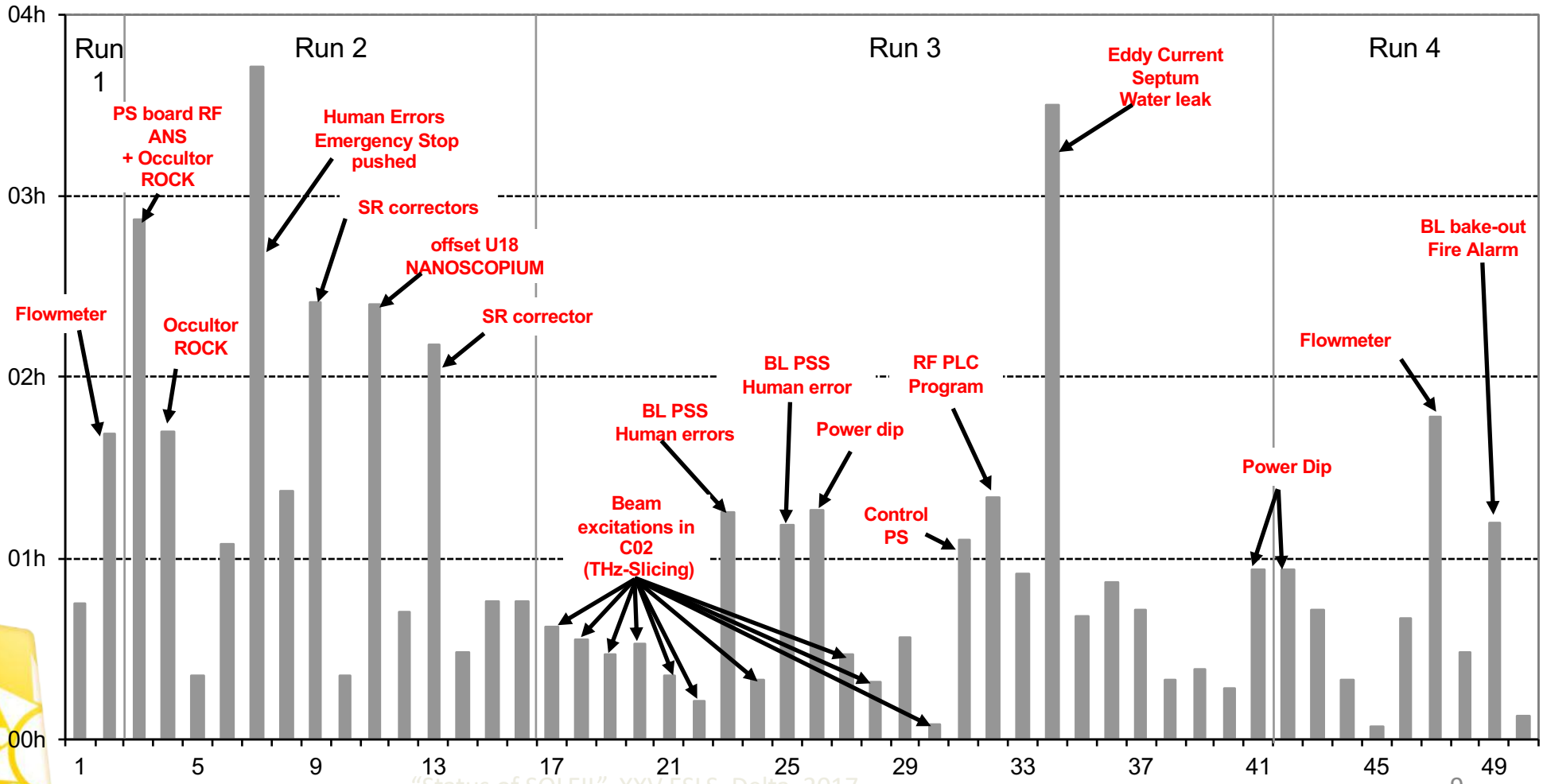
Efficiency during beamlines and RP sessions in 2018
4024 hours of beamtime delivered
represent a beam availability of 98,8 %



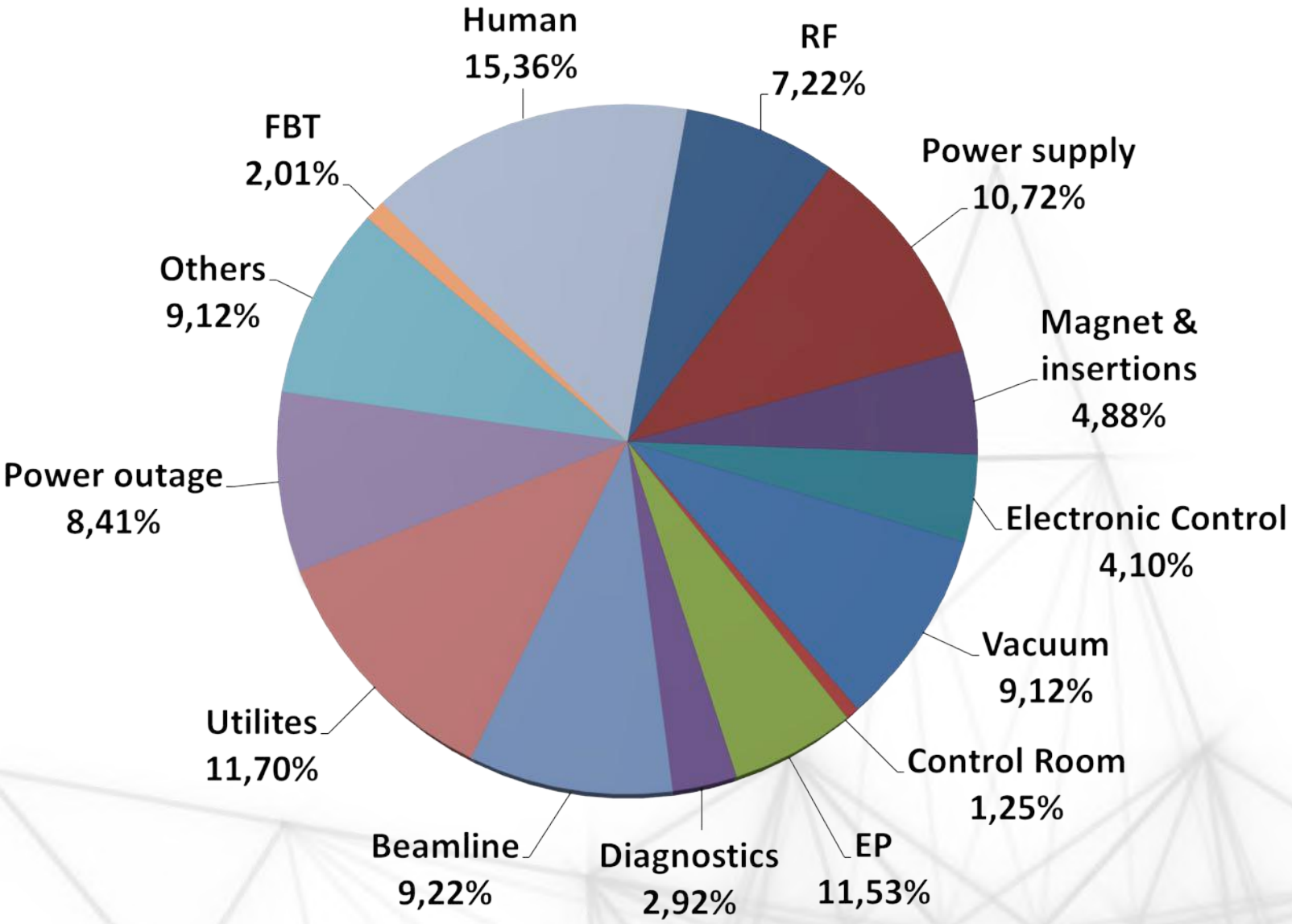
Duration of every interruption (Run 1 to 4)

Time duration of the 50 beam interruptions (beam losses or equipment failures) impacting the beamline or Radiation Safety Tests

Total 49:09
Min 00:04
Max 03:43
Mean 00:58
RMS 00:50

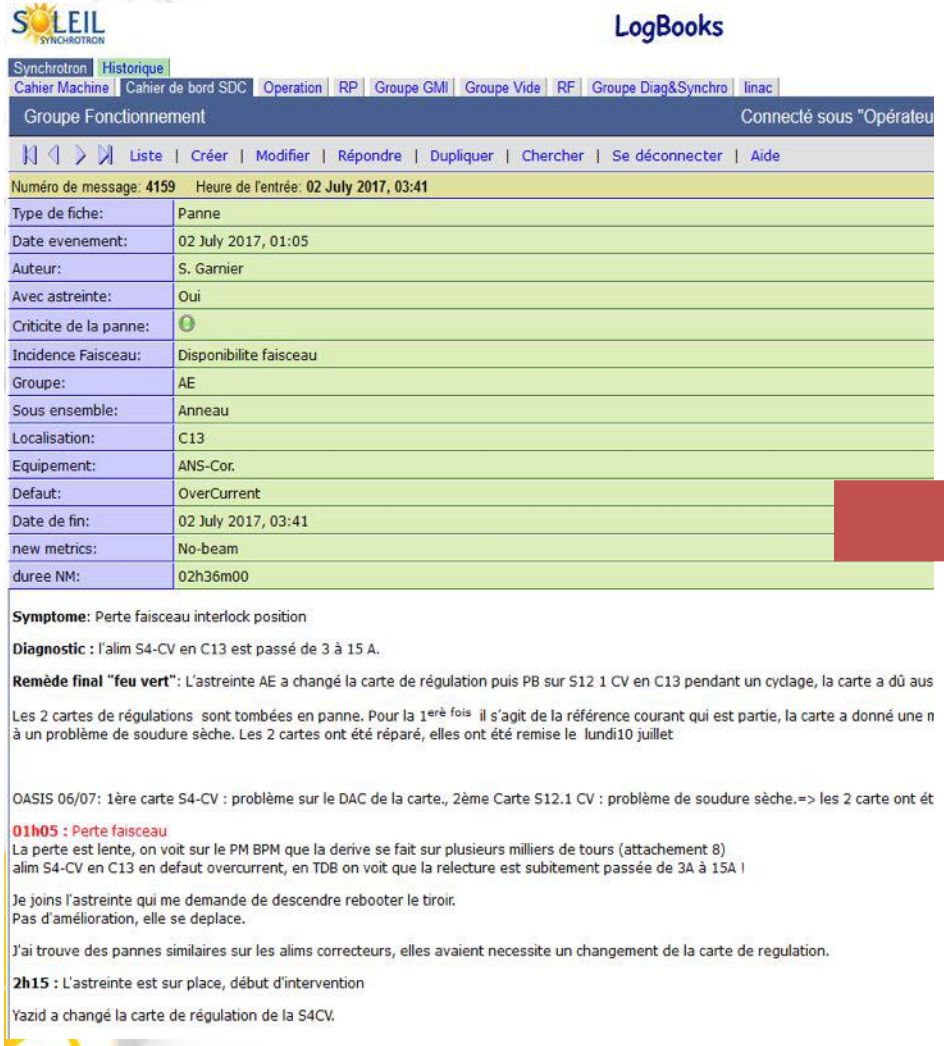


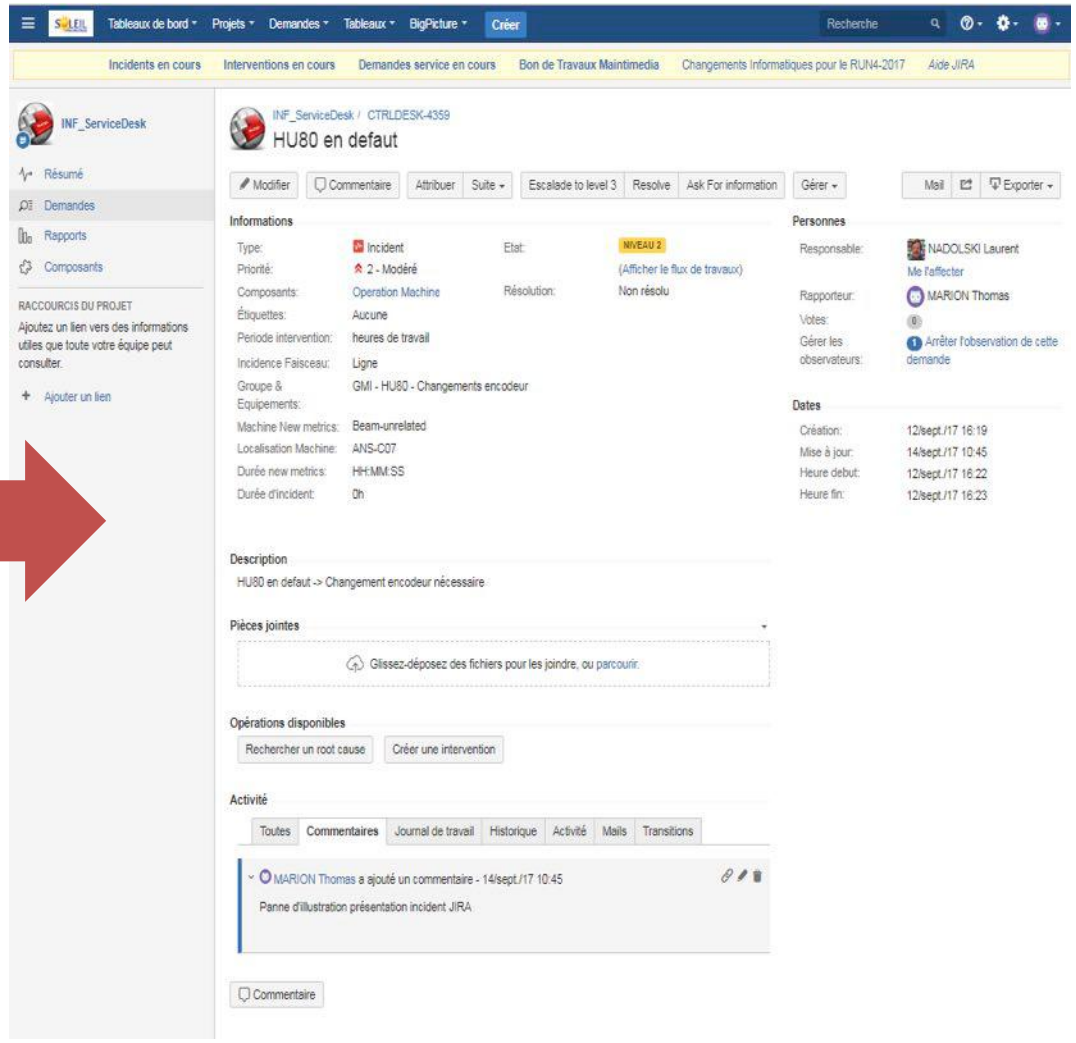
Origins of the 49 Hour Lost Beamtime in 2018 (RUN1 to RUN4)



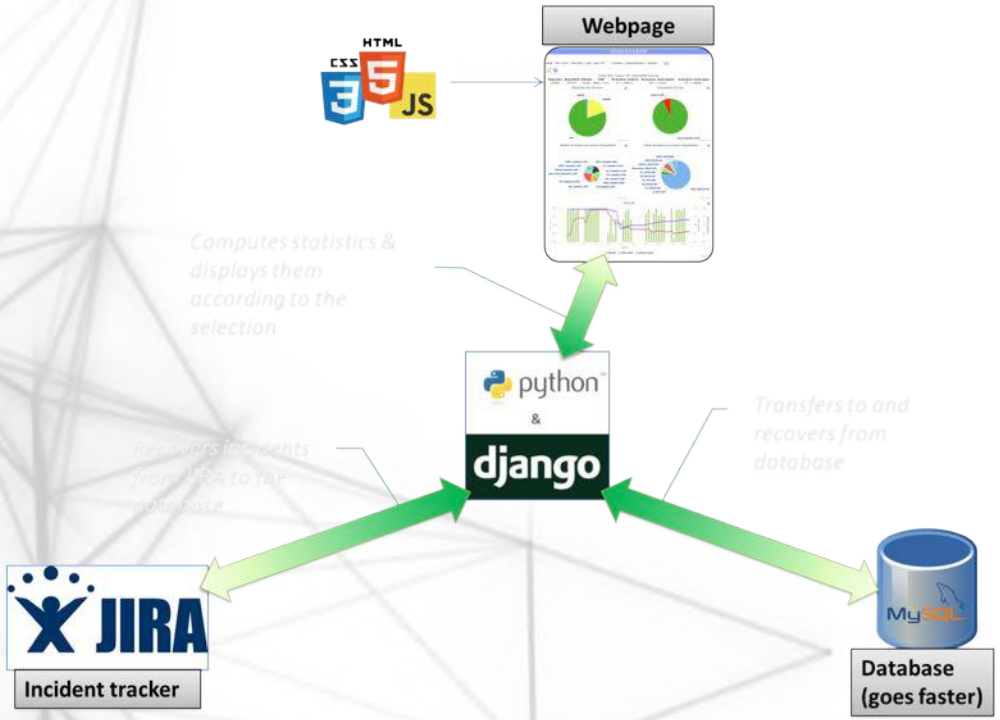
Quality and Incident Management

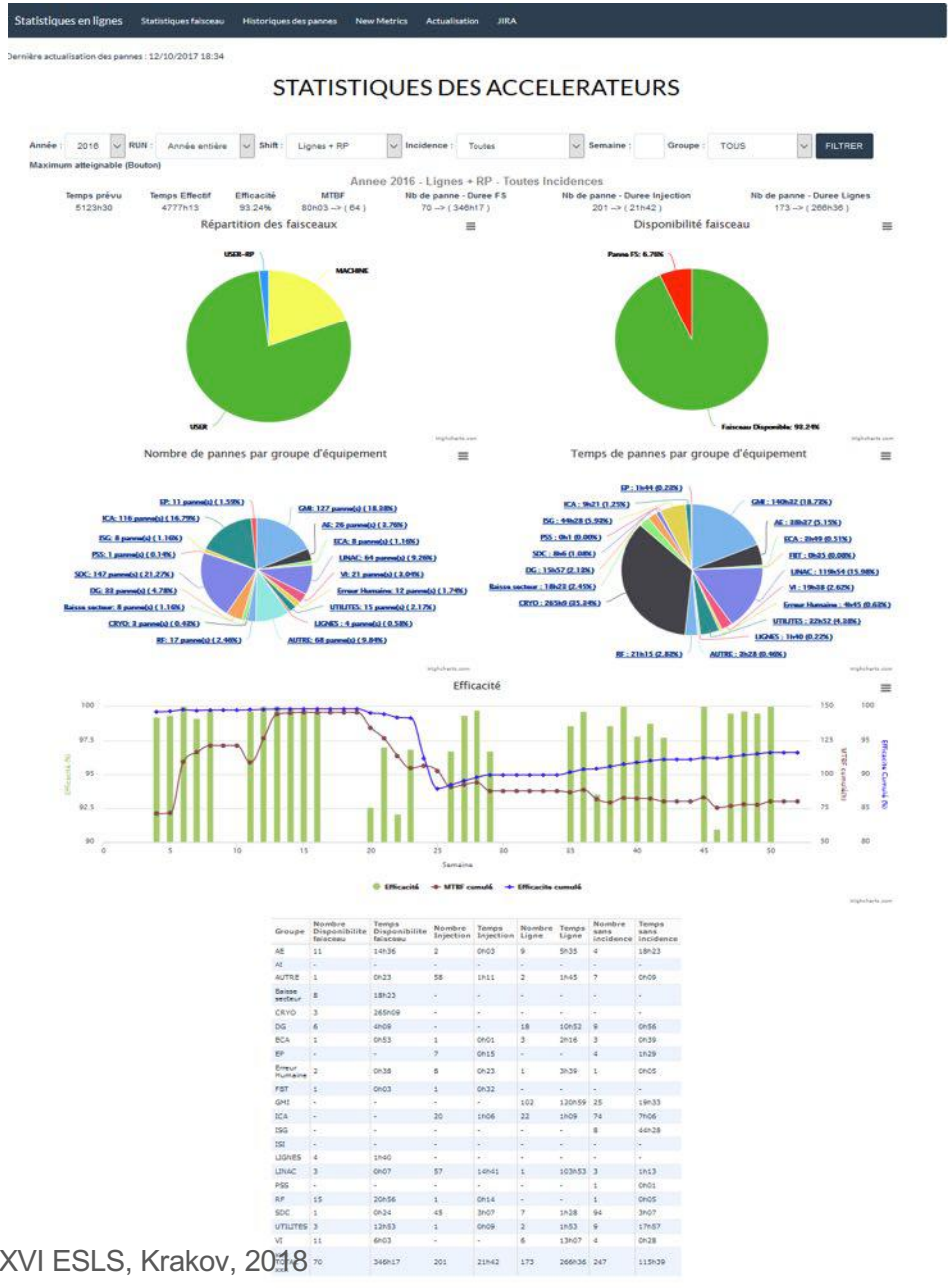
Migration from Elog to JIRA





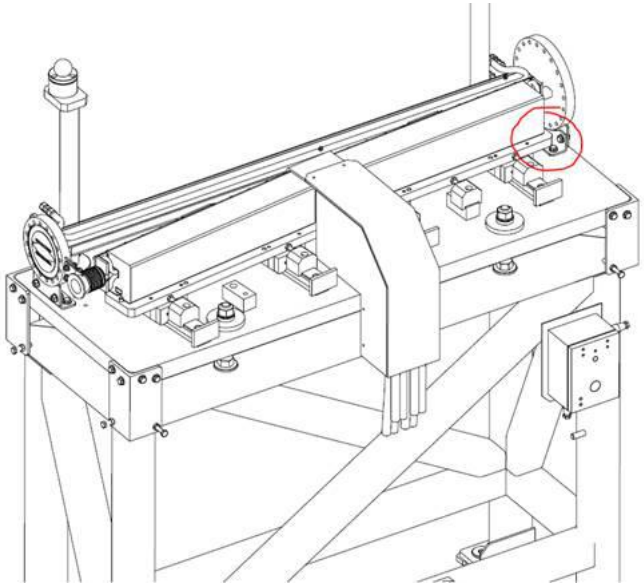
Database and Online Stat-Application developed thanks with DJANGO (Python web-Framework).



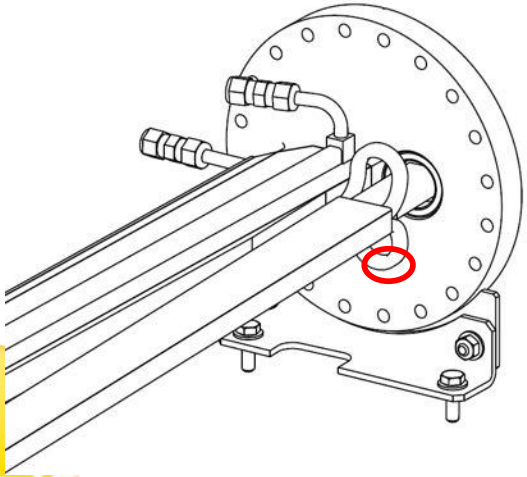


SR Eddy Current Septum: water leak

Detected on June 19th, 2018



Microcracks

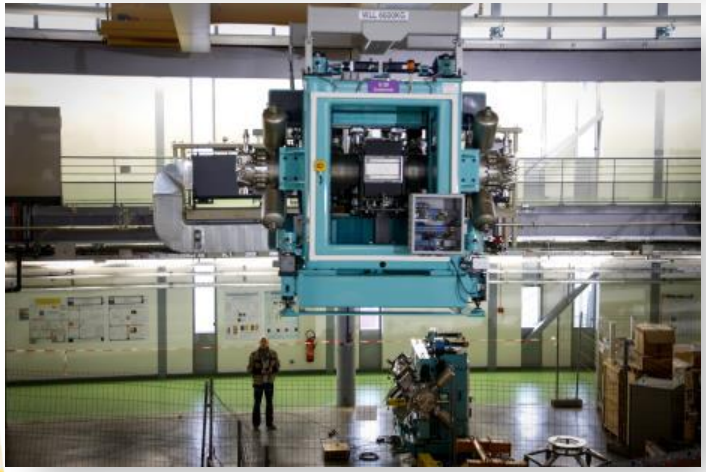


Repairing: difficult
Injection SS: longBacking out
Coil replaced with a spare one during summer shutdown

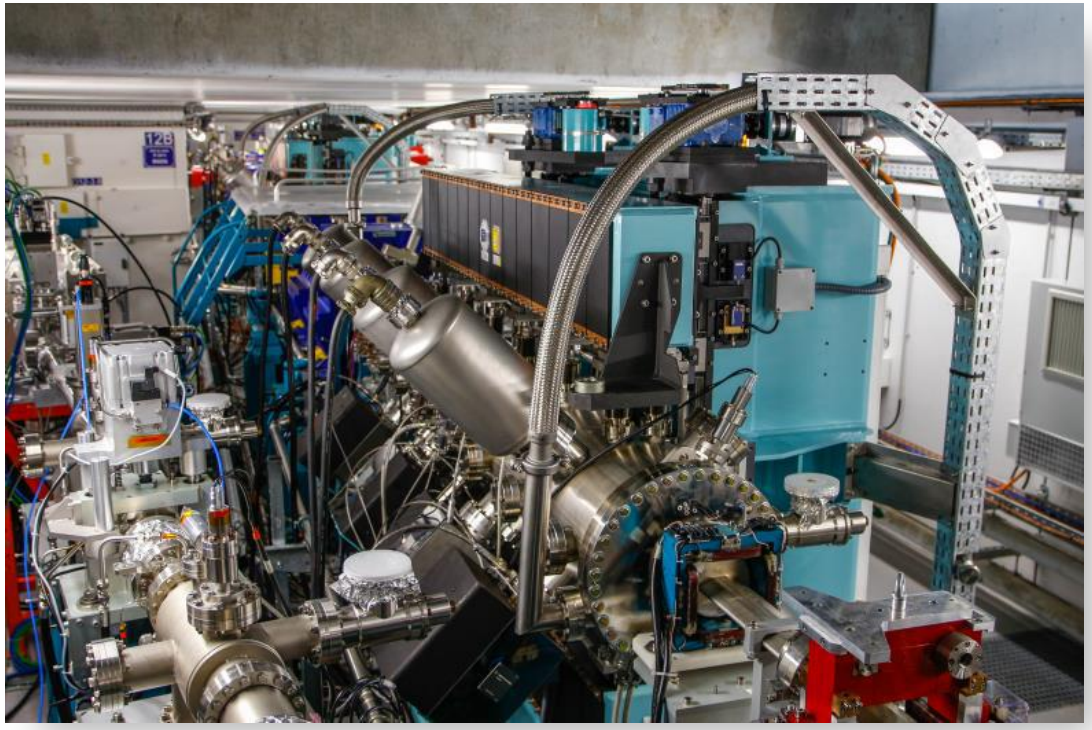
On-going Projects
A Personal Selection

A new cryogenic U18 undulator designed, assembled and measured at SOLEIL has been installed at the end of December 2017 and commissioned with success for ANATOMIX beamline.

Machine radiation safety tests done. Beamlines ones to be performed by end of July 2018.

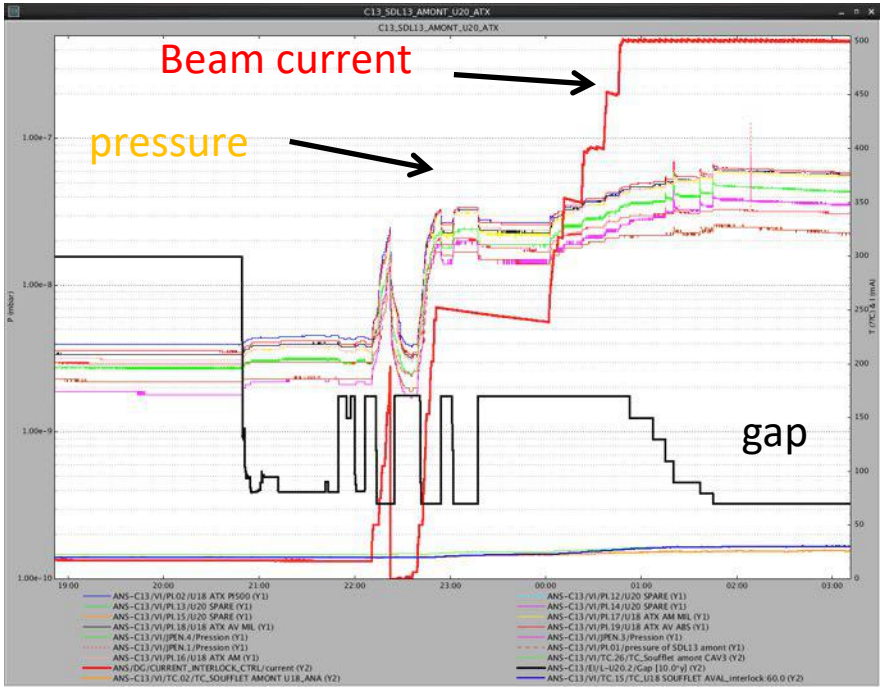


Canted SS with two 5.5 mm in-vac. CMPUs

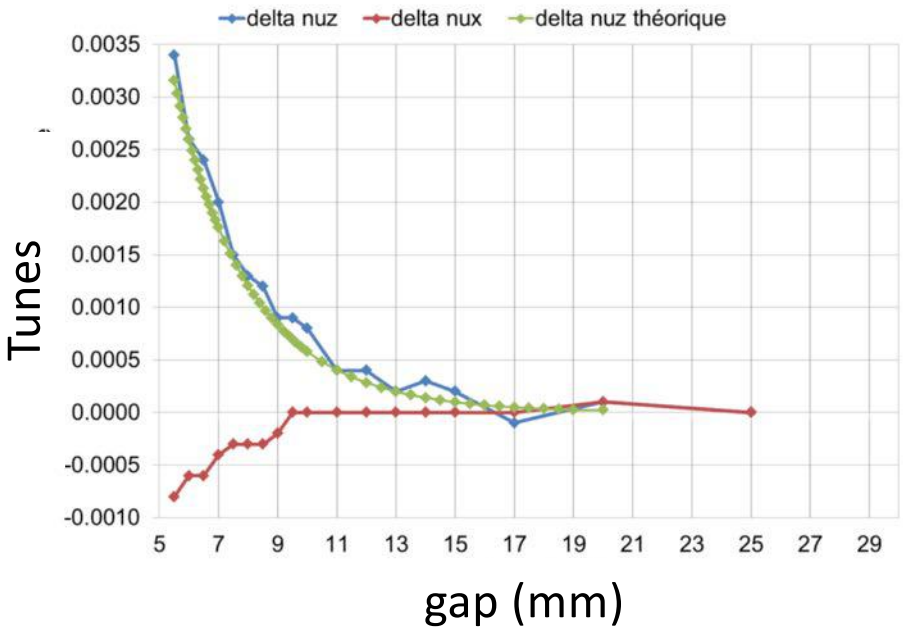


CMPU: Commissioning of U18

Conditioning done quickly
(closing at 7 mm gap and max current 500 mA in 4h)



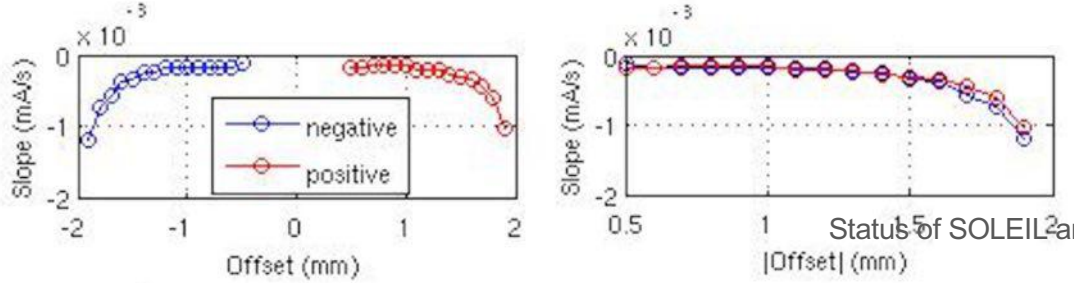
Minimal effects on the beam and consistent with expectations



<u>110 mA in 8 bunches :</u>

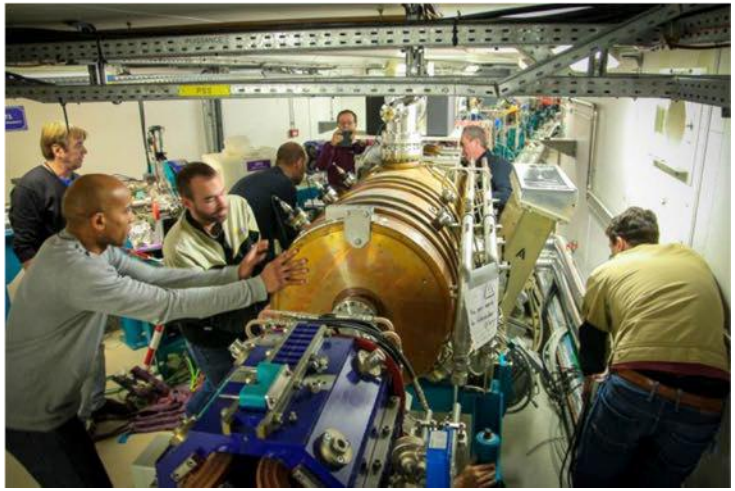
- Variation of 1.2 K only between different filling modes.
- No pressure rise.

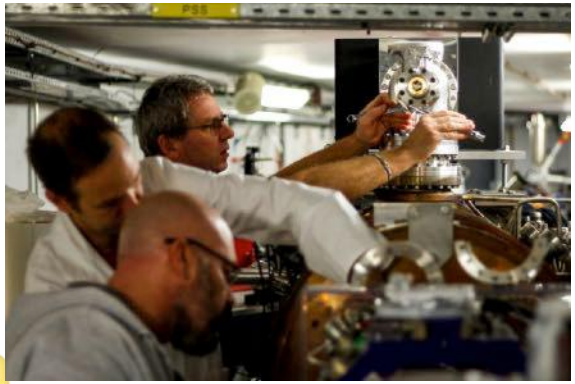
<u>Mechanical vertical offset of 25 µm</u>



Booster RF-system upgrade: Installation of a second RF cavity. In operation since January 2018

RUN3 2018: first test to be done in low-α mode to check the expected increase of injection efficiency and allow new Beamlines to operate in this mode.





Upgrade of the Booster RF system

Present low-α operation suffers from a low injection efficiency (15-20%) due to the long BO bunches
- **→ Heavy safety radiation constraints**
- **→ Prevents more beam lines to join this operation mode**

Implement a 2nd RF station → Increase V_{RF} from 1 up to 3 MV → Double injection efficiency

- **Install our available spare cavity in a BO straight 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 the SR SSPA's, using the 160 RF modules & dc-dc converters, got back from the SR SSPA upgrade**
- **LLRF & Control → a replica of the actual one**
- **Increase V_{RF} of the existing plant from 1 up to 1.2 MV → P_{RF} ~ 35 kW (P_{beam} ~ 0) available**
- **Significant infrastructure work**
- **Additional benefits : Power savings and redundancy for daily operation**

- **2nd RF station in operation since February 2018**
- **Low-α mode commissioning and operation with the double RF system & additional beam lines expected in the coming months**

On-going Magnet power supplies reliability improvements

Power converter operation: Availability is crucial [A = MTBF/(MTBF+MTTR)]

Huge number of power supplies installed on the machine: More than 600

MTBF improvement:

- Careful (re)design to get a high MTBF (> 100'000h)
- Development of remote diagnostic tools to prevent breakdowns (e.g. surveillance of power supplies output ripple, of load impedance variations from one run to the other one)
- Systematic analysis of any dysfunction ; all incidents are traced in JIRA and in the CMMS
- Preventive maintenance (annual rate): Dust removal, tightening of power connections, checking of the cooling fans, infrared analysis in all the cabinets (to detect loose connections, anomalies), measure of the capacitance of the electrolytic capacitors in the bigger converters, diligent follow-up of any subcontracted operations

High MTBF 1kW corrector power supply built in house

Maintenance of the 160 Storage Ring quadrupole power supplies

Reliability improvements of the PSI digital regulation cards (work with DIAMOND)

MTTR improvement:

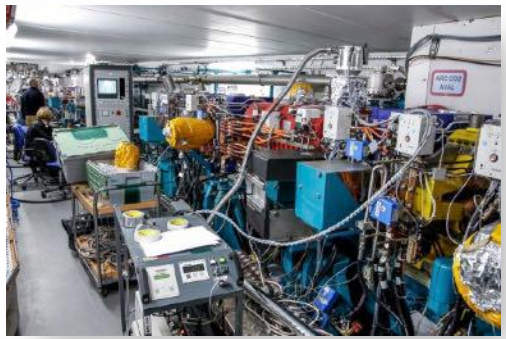
- Construction of additionnal switchable spare units
- Diagnostic enrichment, allowing quicker detection of faulty element, using PLCs
- More detailed procedures for on-call interventions

50 kW spare power supply built in house for the Storage Ring sextupoles / TL2 dipoles

Management of obsolescence is also a major concern:

- Work to identify the critical parts at risk of going obsolete
- Elaboration of ad hoc strategies: Buying and storing critical parts, finding non-obsolete substitute parts, localized or complete redesigning

New THz Beamline for the Femtoslicing Experiments



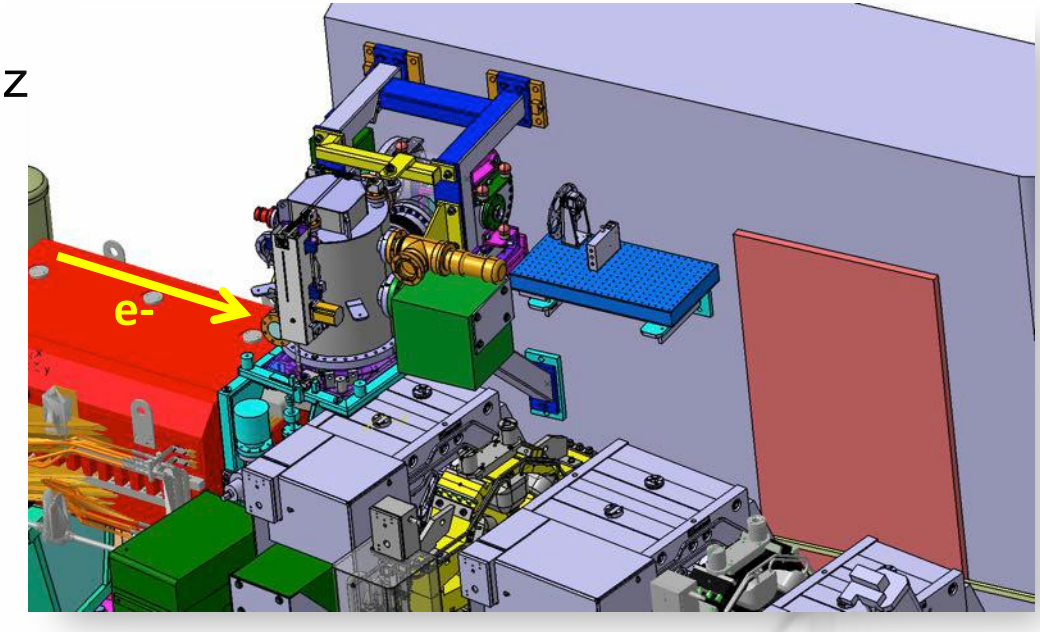
Aim:

- Femtoslicing experiments rely on laser / e- interaction
- For long term STABLE Femtoslicing: feedbacks required
- Input for feedback = coherent THz intensity in a storage ring dipole

→ New beamline to extract coherent THz signal on C02-D2

Beamline components (all in tunnel):

- Three mirrors (2 planar + 1 toroidal) to extract/focus/transport the THz signal over ≈ 2 m
- A diamond window to propagate the THz
- A diode to measure the THz intensity



Schedule:

- Design: October 2017 - July 2018
- New vacuum chamber installed in May 2018.
- End of installation: January 2019
- Commissioning: January-March 2019

21°C Cooling Circuit Leaks on Brazing Joints and Clogging

- **Since April 2017, 5 leaks on brazing joints**
  - 2 on HU640 10 m long ID
  - 2 on SR sextupole and 1 SR quadrupole
- **Significant increase of clogging events**
  - @filters, @pressure redactor at BPM locations, etc.
  - Cu oxide residues, whitish precipitations
- **Concern about aging of the 21°C cooling circuit**
  - **Survey/**experience of other facilities on similar issues
  - Improve **on-site brazing expertise** and training (4 people)
  - Revisiting **erosion/corrosion process** and water chemistry
  - Need to increase **online measurement capability** (pHmeter, dissolved oxygen)
  - **Revisiting procedures** to avoid introducing dissolved oxygen in the circuit (during maintenance, flushing, make-up water, etc.)
  - **Expertise with CEA** (service de la corrosion et du comportement des matériaux dans leurs environnements): report and recommendations expected by end of June 2019

HU640

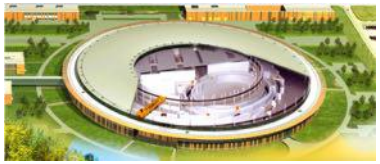
HU640 brazing joint

Clogging @ Filter

Whitish residue

Quadrupole leak

Upgrade of the SR RF system



1) The last of the 4 new SR cavity input couplers was implemented in 2017
   All of them were tested up to 270 kW with beam
   Overheating on coupler_3 to be solved

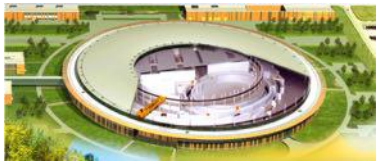
2) Modification of the waveguide network, using SOLEIL Magic Switches
   → Allow combining the power from 2 SSPA's into one cavity

3) Refurbishment of the 180 kW Solid State Power Amplifiers (SSPA's)
   (New transistor & upgrade of the 2.5 kW combiners)
   → More robust transistor & lower thermal stress → much less module failures → less maintenance
   → Higher power capability (P_{mod} : 310 W → 450 W) → Store full I_{beam} with only 3 running SSPA's
   → 7 dB transistor gain → 160 pre-amp modules & their dc PS are got back for the new BO SSPA
   → Electrical power savings (efficiency : 50 % → 60%) compensate the investment cost in < 3 years

Present Status : 1.5 refurbished SSPA (6 towers, ~ 1000 modules)
→ 450 mA with 3 running SSPA's or 500 mA with 3 running cavities

Going on at a rate of 4 towers a year (SOLEIL + external resources),
completed early 2020 → 500 mA with 3 running SSPA's / cavities
or 450 mA with a single cryomodule, combining 2 SSPA's per cavity

Other ongoing RF projects

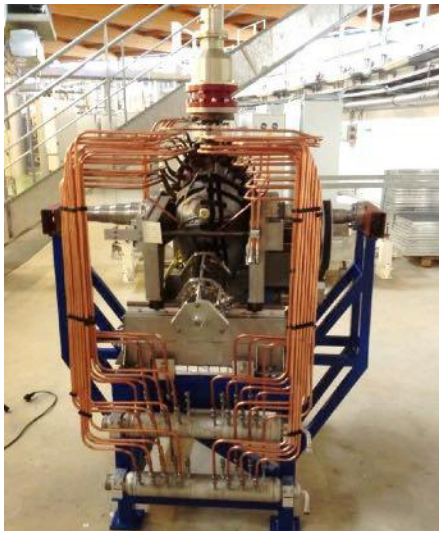


- **Four 500 MHz – 80 kW SSPA's supplied to SESAME**
  - The 1st one was built by SOLEIL as a demonstrator
  - The 3 other ones were built on the same model by SigmaPhi Electronics (SPE), the SOLEIL licensee
  - They are in operation in the SESAME SR since May 2017 (commissioned by SOLEIL and SPE)

SESAME 80 kW SSPA

- **ThomX 3 GHz LINAC & 500 MHz SR RF system (Cavity, 60 kW SSPA, LLRF, FBT)**
  - All the equipment delivered end of 2017
  - Installation & commissioning → 2018 – 2019

ThomX cavity

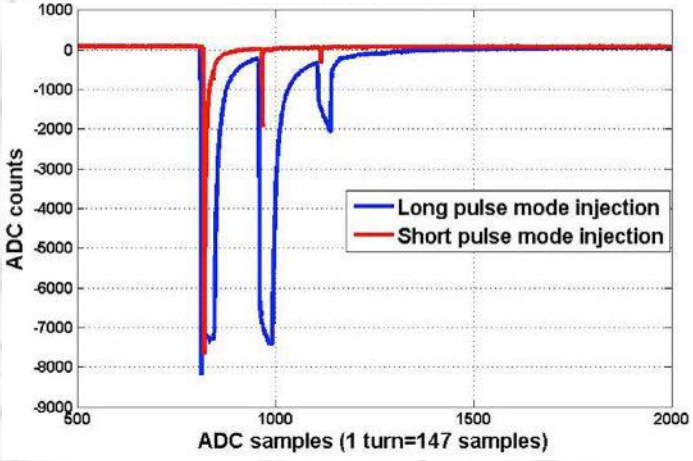


- **LUCRECE / LUNEX5 : R&D about RF technology for CW LINAC (2016 – 2020)**
  - A 1.3 GHz 9-cell sc cavity (LCLS2 type) is about to be ordered
  - 20 kW CW input power coupler → R&D (CNRS-LAL, SOLEIL, Thales)
  - 1.3 GHz - 20 kW SSPA (GaN transistors) → R&D (SOLEIL, SPE)
  - LLRF → R&D (SOLEIL, CNRS-LAL)
  - Tests of the assembly in CryHoLab at CEA (CEA, SOLEIL)

- **Preliminary study of the RF system for the upgrade of SOLEIL towards a DLSR – VSR**
  - Main 352 MHz system with longitudinal phase kick for on-axis injection
  - Harmonic RF systems for bunch lengthening and shortening

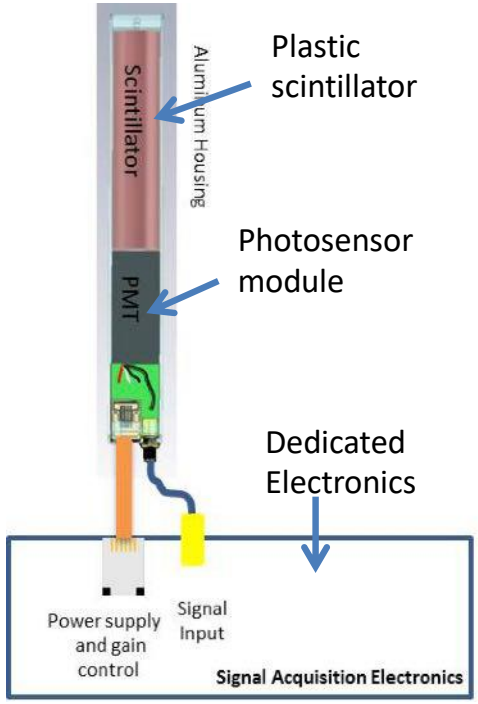
New Beam Loss Monitors

- **Objectives:**
  - Measurement of fast and slow losses with the same system.
  - Improvement of the relative calibration between modules.
  - Improvement (reduction) of the sensor directivity, compared to the current system (coincidence pin diodes).



Beam losses at injection behind closed scraper. Filling pattern (Single bunch vs. 104 bunches) can be clearly identified on the losses signal due to the high temporal resolution.

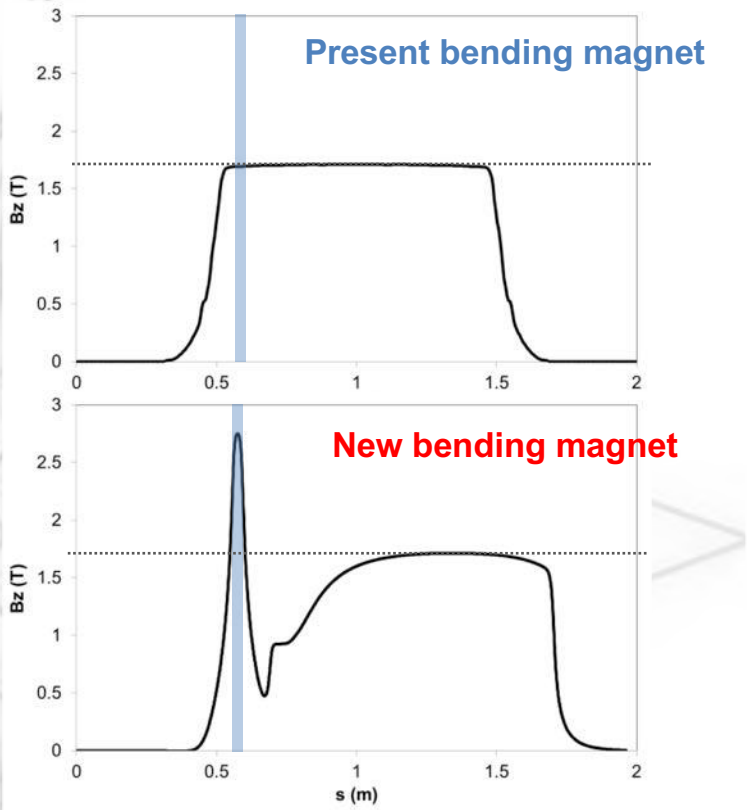
4 BLM installed behind the vertical scraper.

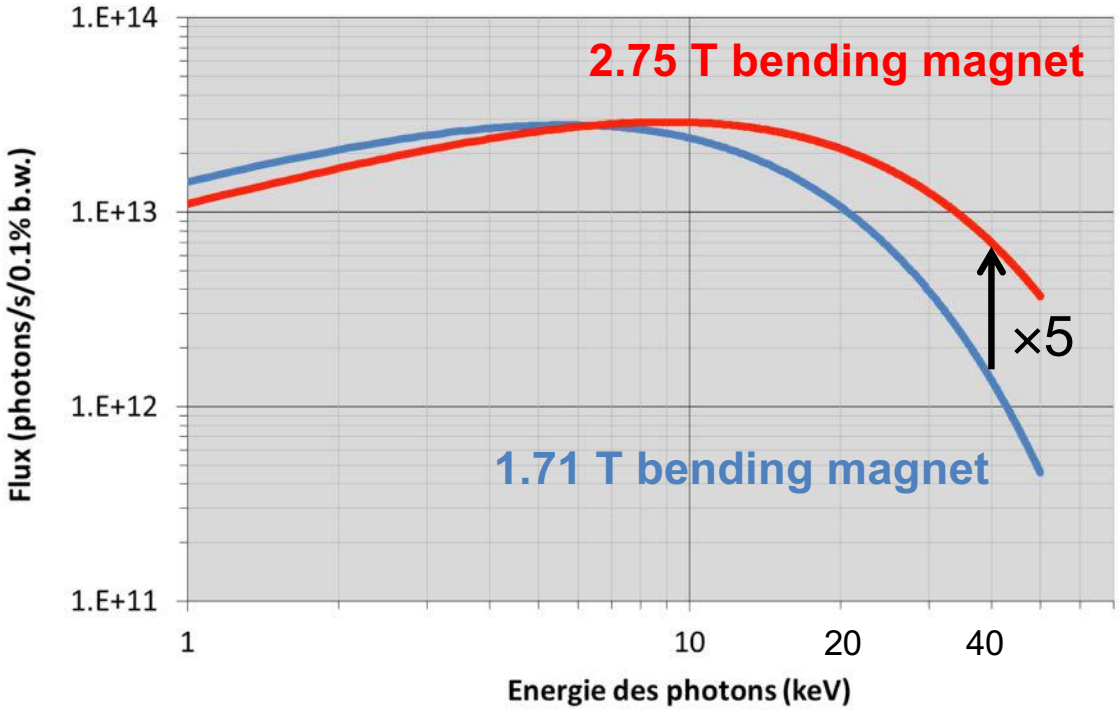


- 4 BLMs tested in 2018
- 2 cells will be fully equipped (10 BLMs/cell) in early 2019
  - Selection of the best locations
  - Use of the data to validate radiation protection simulation codes
- All the storage ring equipped by the end of 2019 (4 BLMs/cell)

New Bending Magnet for ROCK beamline to increase the Photon Flux at high energy

- The strong field is created for the beamline only (exit port 1 °, opening 1.5 mrad)
- The weak field must not exceed 1.7 T to keep the same power to be absorbed by the machine





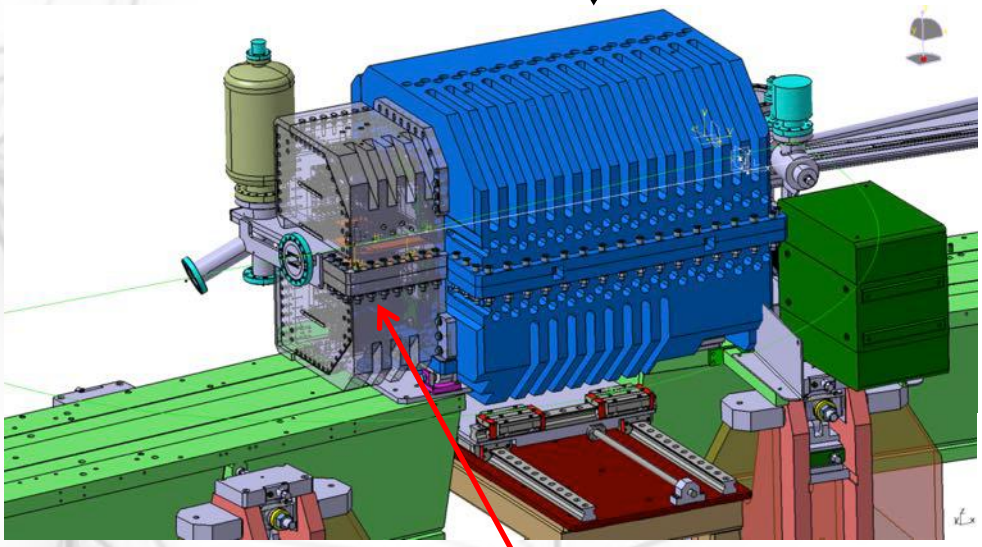
Photon flux calculated at 8700 mm from the source point in an aperture of 3 x 2.4 mm²

➢ **New bending magnet to be installed in August 2020**

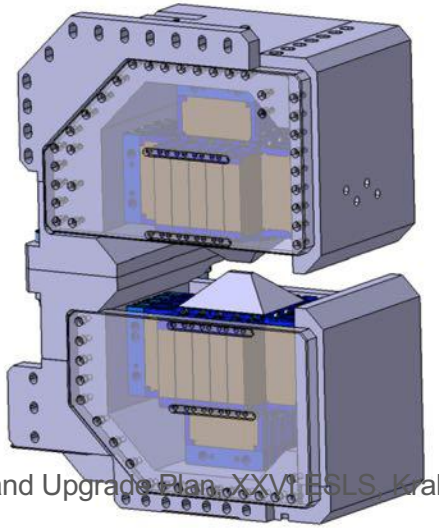
ROCK Beamline: Progress in the design of the magnet and the vacuum chamber

Magnet Ensemble design

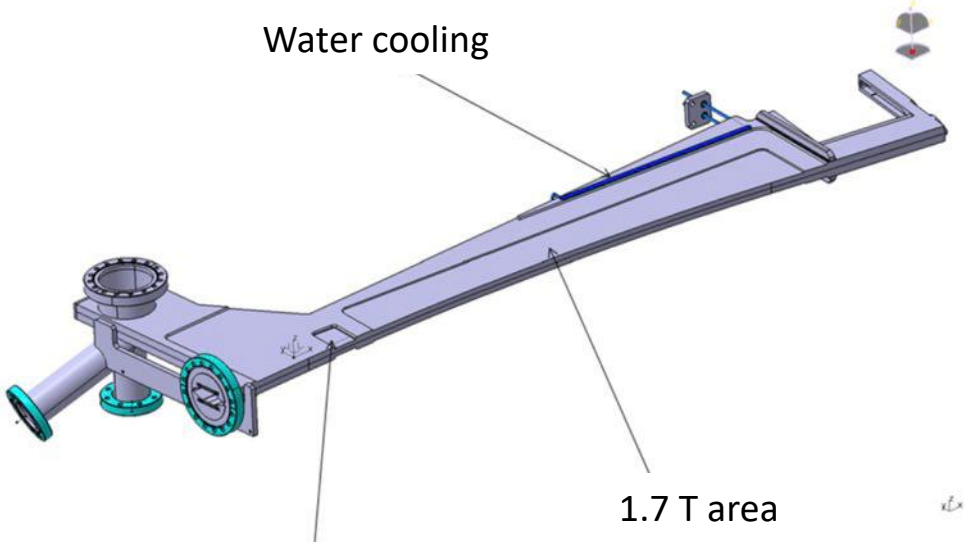
Low field Magnet (1.7 T)



High field Magnet (2.7 T)



Vacuum Chamber design

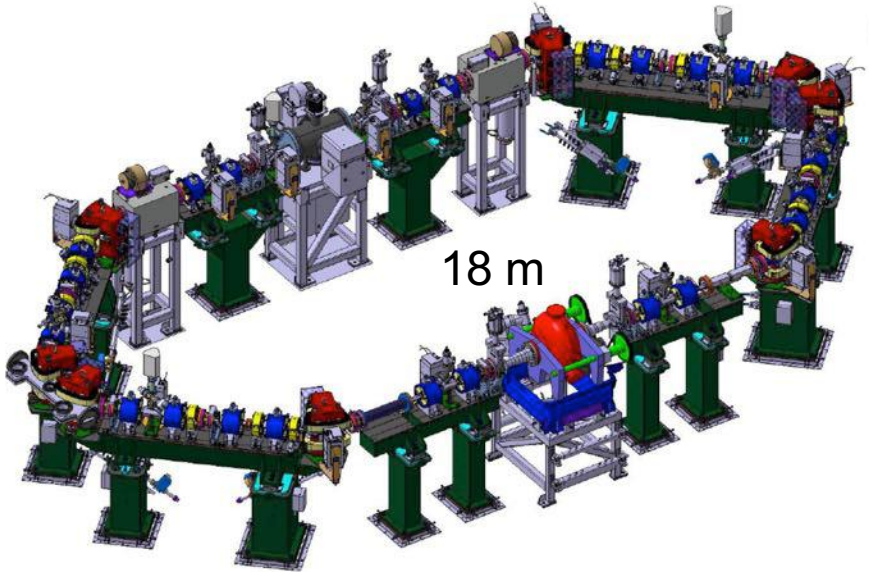


Compton Back Scattering X-ray Source

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



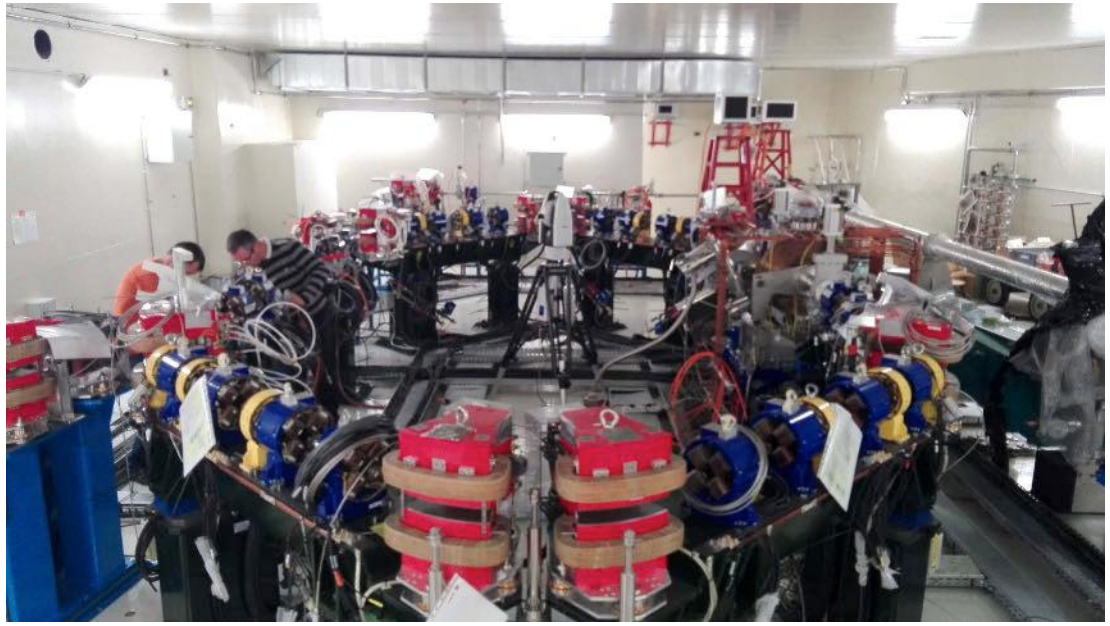
Status

All installation should end by March-2019

Commissionning :

Linac	**April-2019**
Fabry-Perot cavity	**June – 2019**
Ring	**September - 2019**

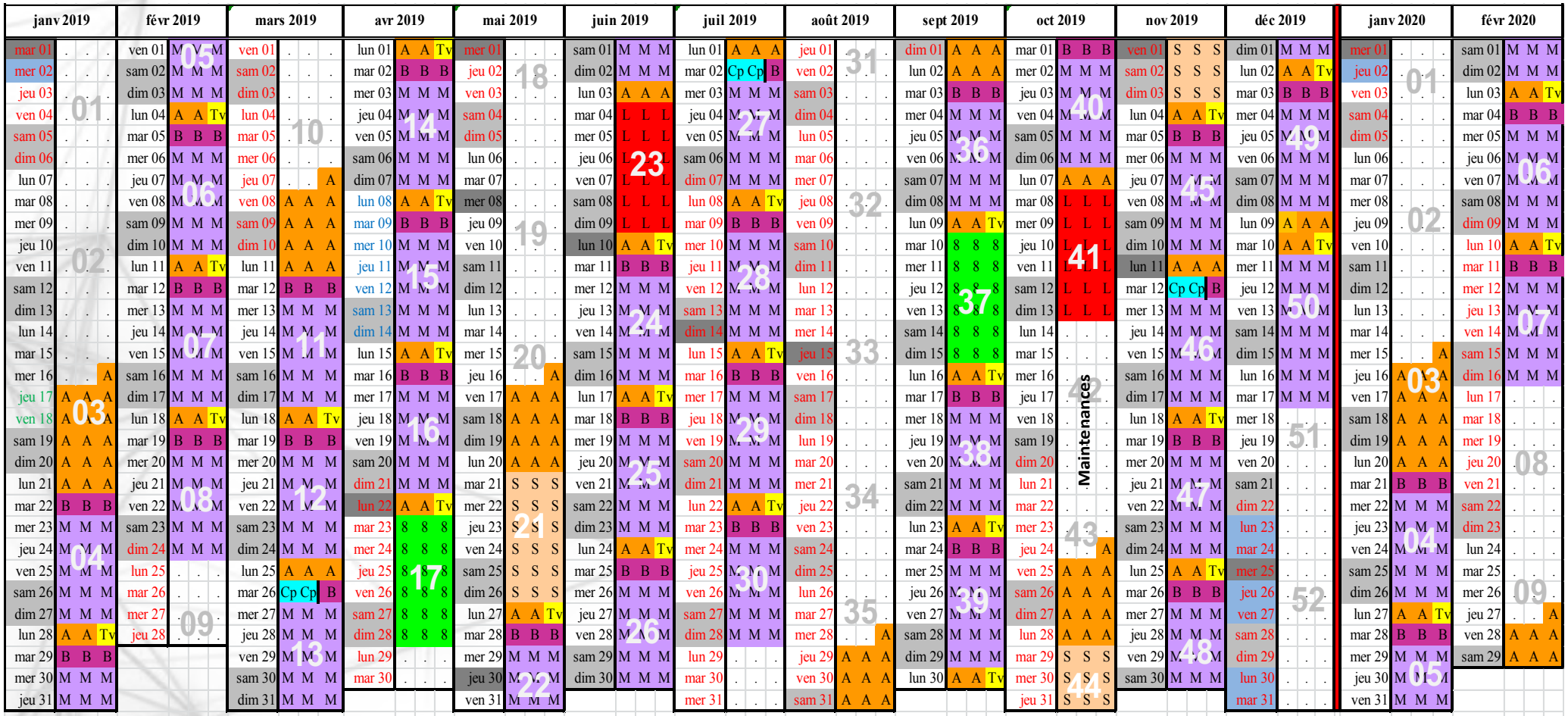
First photon by end of 2019



Installation almost completed
Missing pulsed magnets and few connecting pipes

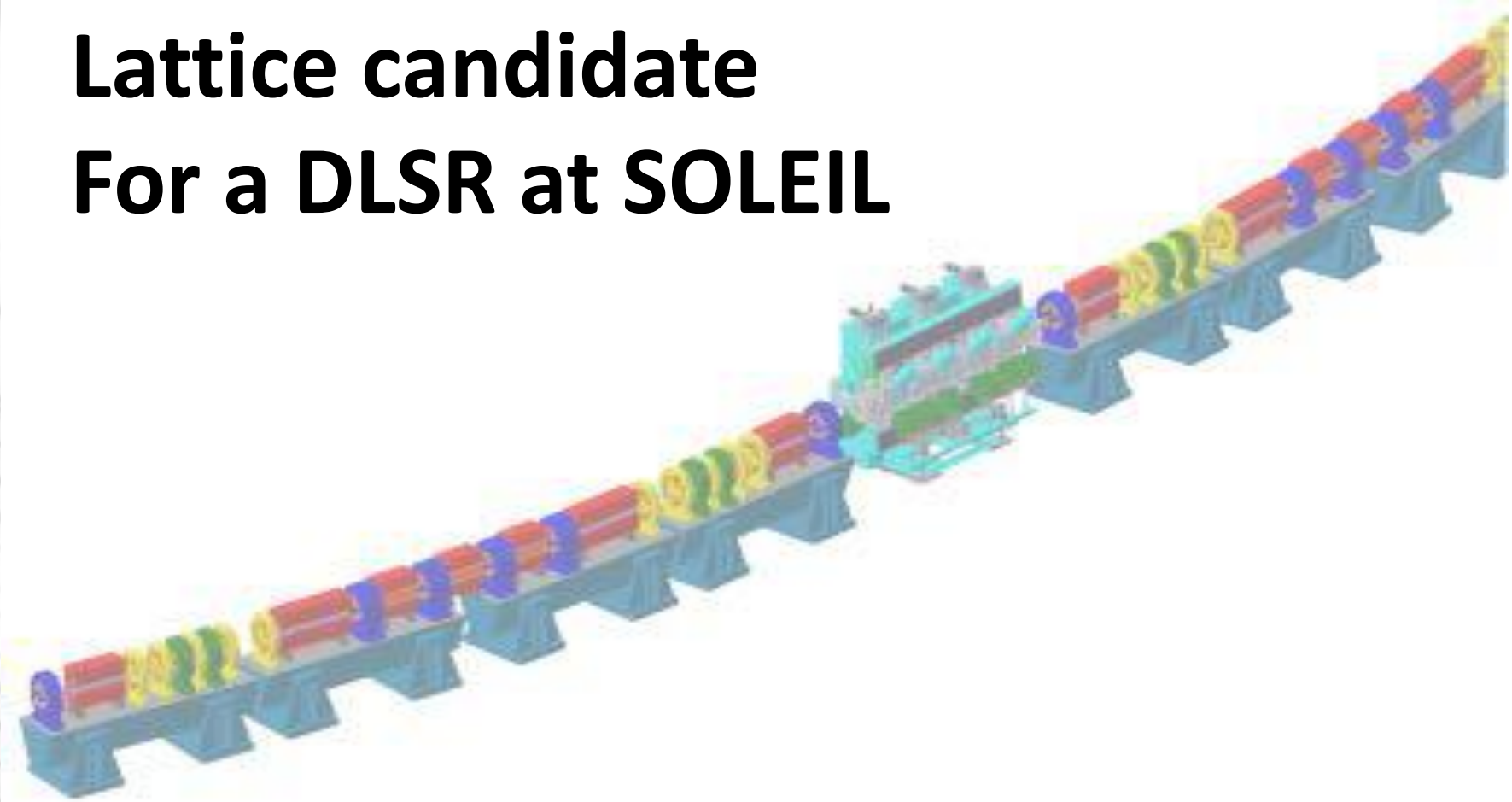
Beam Time Schedule in 2019

5019 hours for the beamlines



M	Uniforme 500mA ou Hybride 450 mA - Top-Up
8	8 paquets Top-Up - 100mA
S	1 paquet Top-Up - 16mA
L	Low-Alpha Top-Up
B	Beamlines
Cp	Contrôles RP périodiques, 3 mardis de 7h à 23h
Tv	Tests RP de validation, faisceau Lignes suivant à 10h
A	**Temps Accélérateurs**
.	Arrêt Machine

Lattice candidate
For a DLSR at SOLEIL

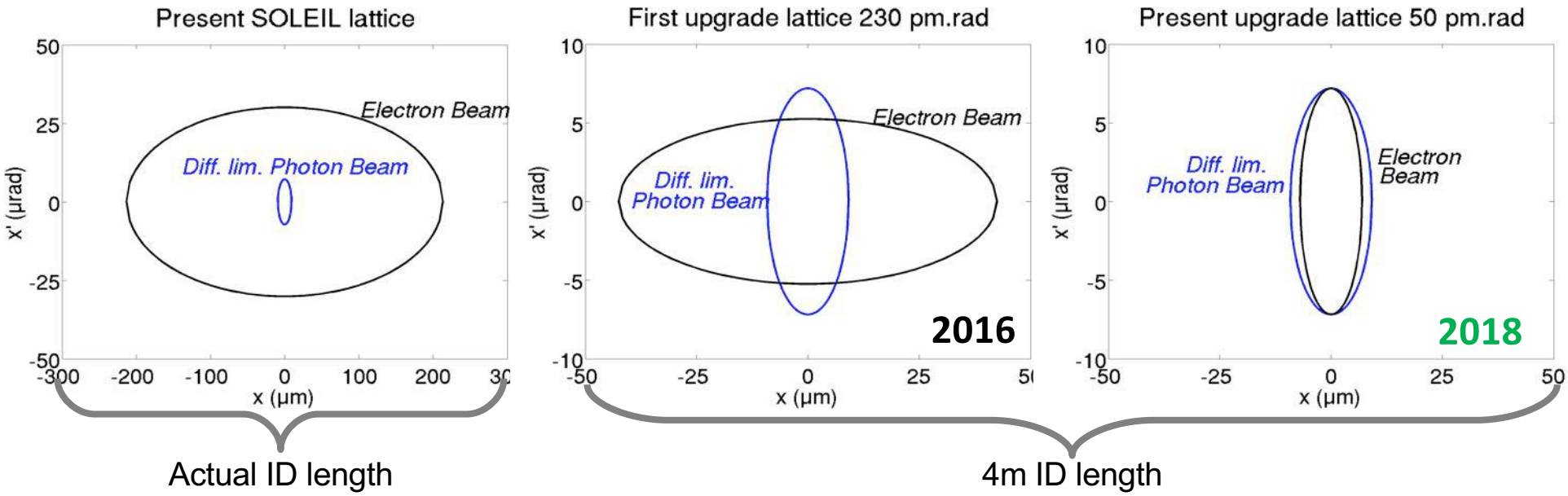


Boundary Conditions and Constraints

- 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 **as much as possible**.
- 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** as much as possible of the **injector complex**: linac and booster.
- **Reuse** much of the **technical infrastructure**.
- Provide alternative radiation sources for the existing **bending magnet based beamlines.**
- **Innovative insertion devices** to cover low to high energy spectrum (IVU: ≤ 4mm full gap)
- Preserve **Infra-Red (IR) beamlines**
- Preserve the location of the **MARS radioactive beamline**
- Preserve the location of **long canted beamlines (150/200 m long BL)**
- Limit downtime to a **maximum of two years**.
- **Minimize operation costs**, in particular the wall-plug-power.

Goal: Electron-Photon Matching at 3 keV

Evolution



Diffraction limited photon beam emittance is 65 pm.rad at an energy of 3 keV $\beta_{matched} = L/\pi \approx 1.27\,m$ **for a undulator of 4 m**

With 50 pm.rad and $\beta = 1\,m$ **the beam size is 7 µm and 7 µrad RMS in divergence in both planes at source.**

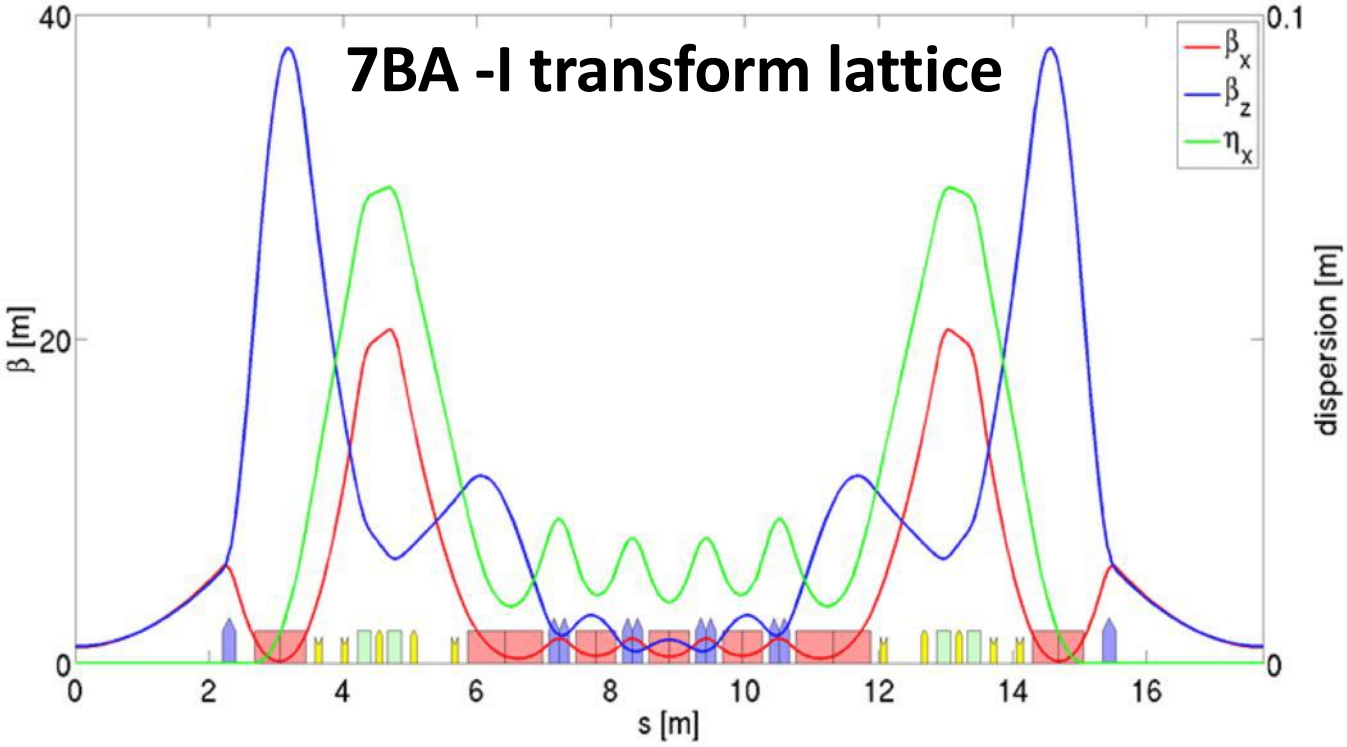
New Lattice Candidate

2.75 GeV
354 m

ε_x = 72 pm.rad 20 cells – 20 straights sections

L_{SS} = 4.4 m avec $\beta_x = \beta_z = 1$ m

A. Loulergue et al., IPAC'18 doi:10.18429/JACoW-IPAC2018-THPML034

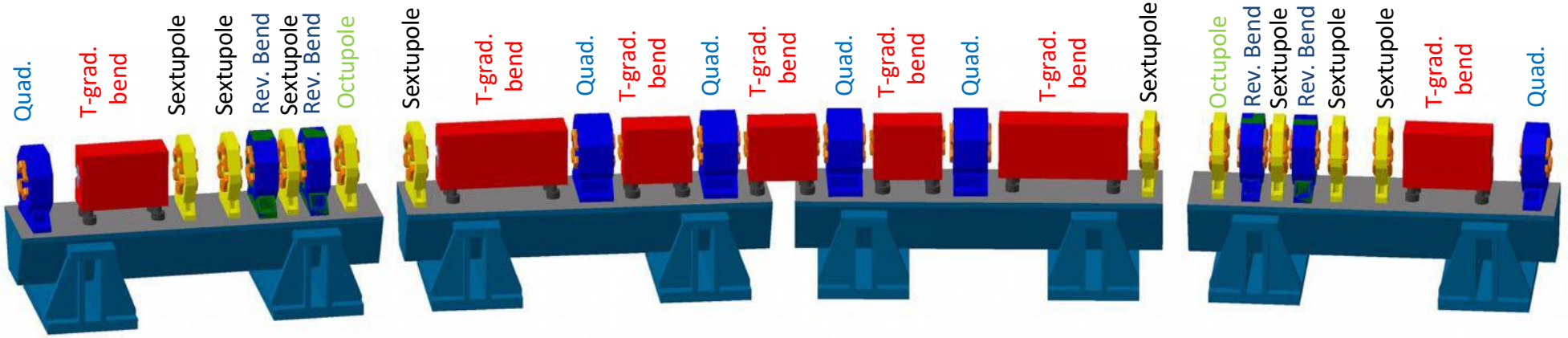


– Sext < 2000 T/m²
– Quad < 100 T/m
– Dip ~ 0.6 T & 40 T/m

Nat. Chro. = -6.7 / -6.3 per cell
= -135 / -125 total

Use of anti-bends
Use of gradient dipoles

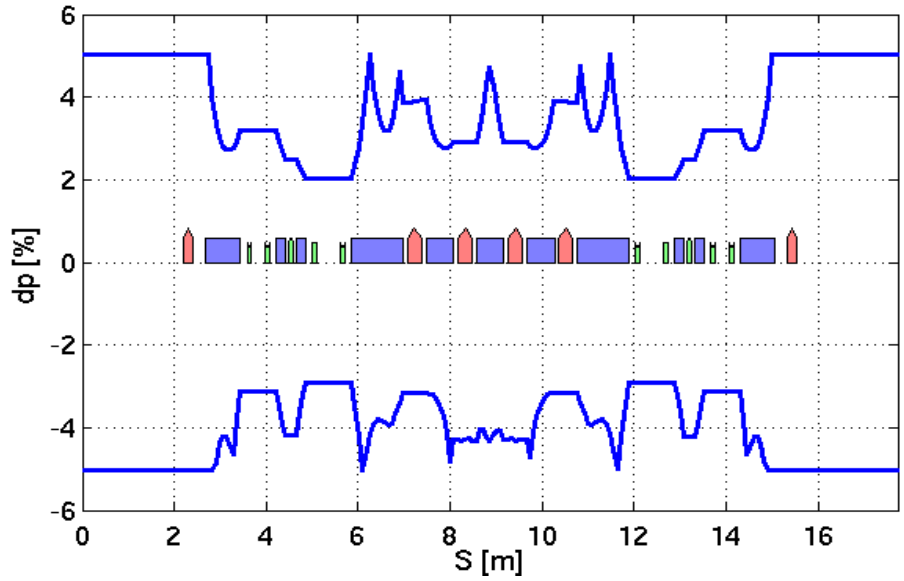
No longitudinal gradient in dipoles

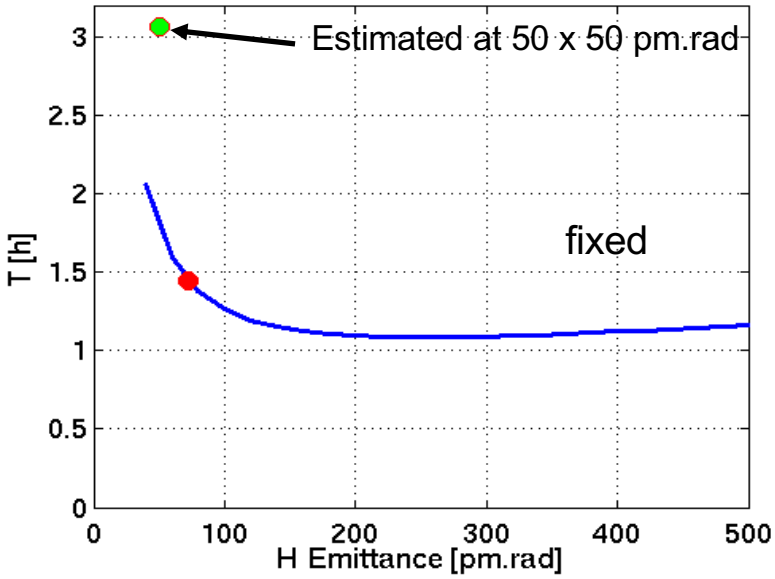


Touschek Lifetime

Perfect lattice
AT2.0

Momentum acceptance





Beam pipe diameter of **<16 mm**
RF Voltage of 1.1 MV
Natural bunch length of 3.7 mm RMS

With 72 in H and 10 in V pm.rad the beam lifetime is about 1.5 h at 500 mA
(1.4 nC per bunch)

Up to **3 h at full coupling (50 x 50 pm.rad)**

Simple horizontal emittance scan
Seems to be on the good side

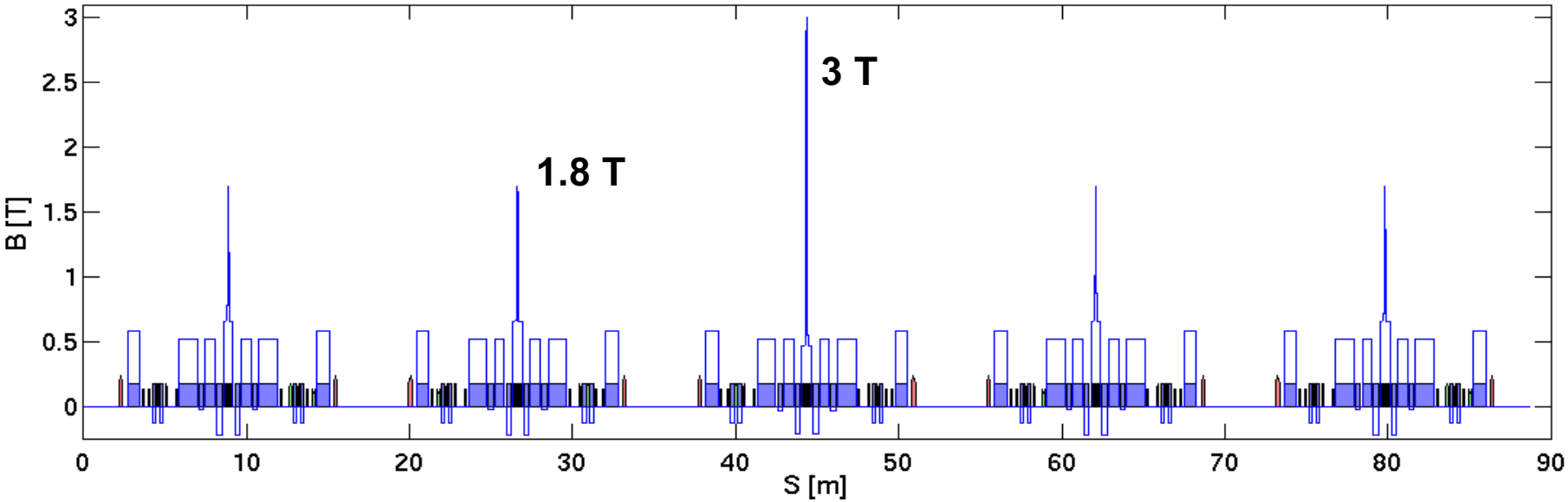
No bunch lengthening by means of third harmonic here

Limited IBS Effect

Emittance increase by 30 % with natural RMS bunch length (3.7 mm / 0 mA)
Limited to 10 % with RF harmonic bunch lengthening (x 5)

3 T Super-Bends + 1.8 T Bends

1/4 of the ring



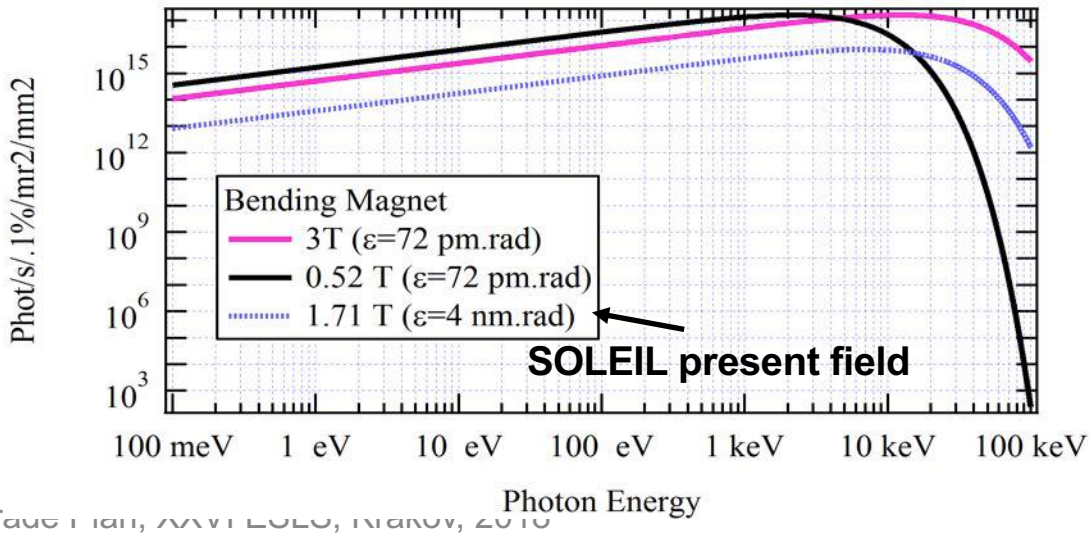
Add 1.8 T on central bend of other cells to reduce back the emittance ~ 70 pm.rad

Insertion of **3T super-bend** in the central magnet of the cell

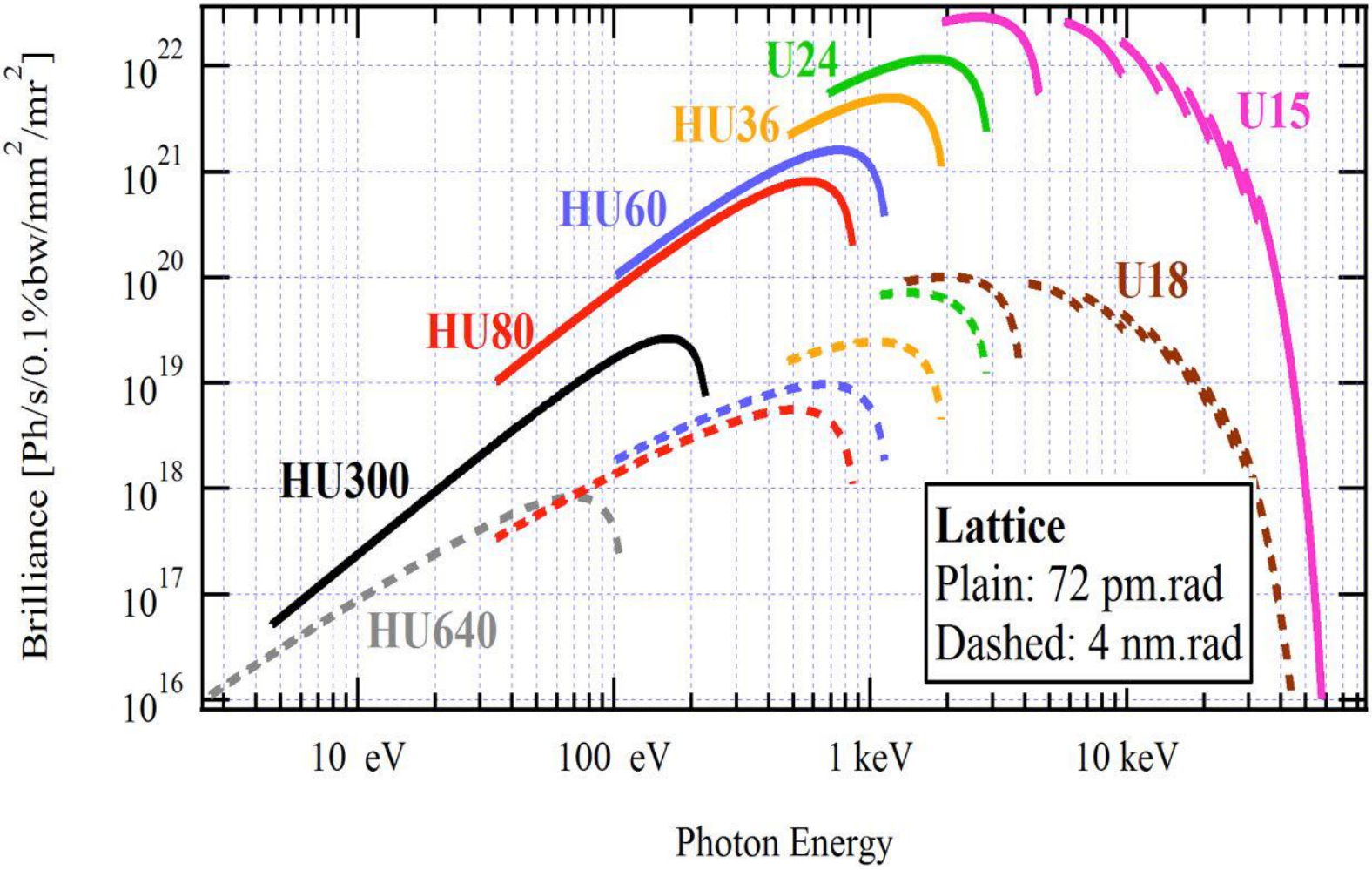
To **increase the photon flux above 10 keV**

4 are foreseen, one each 5 cells

Emittance impact is not negligible
The present H-function is not well suited
→ 1.8 T bend + **benefit of anti-bend**



Photon Brilliance

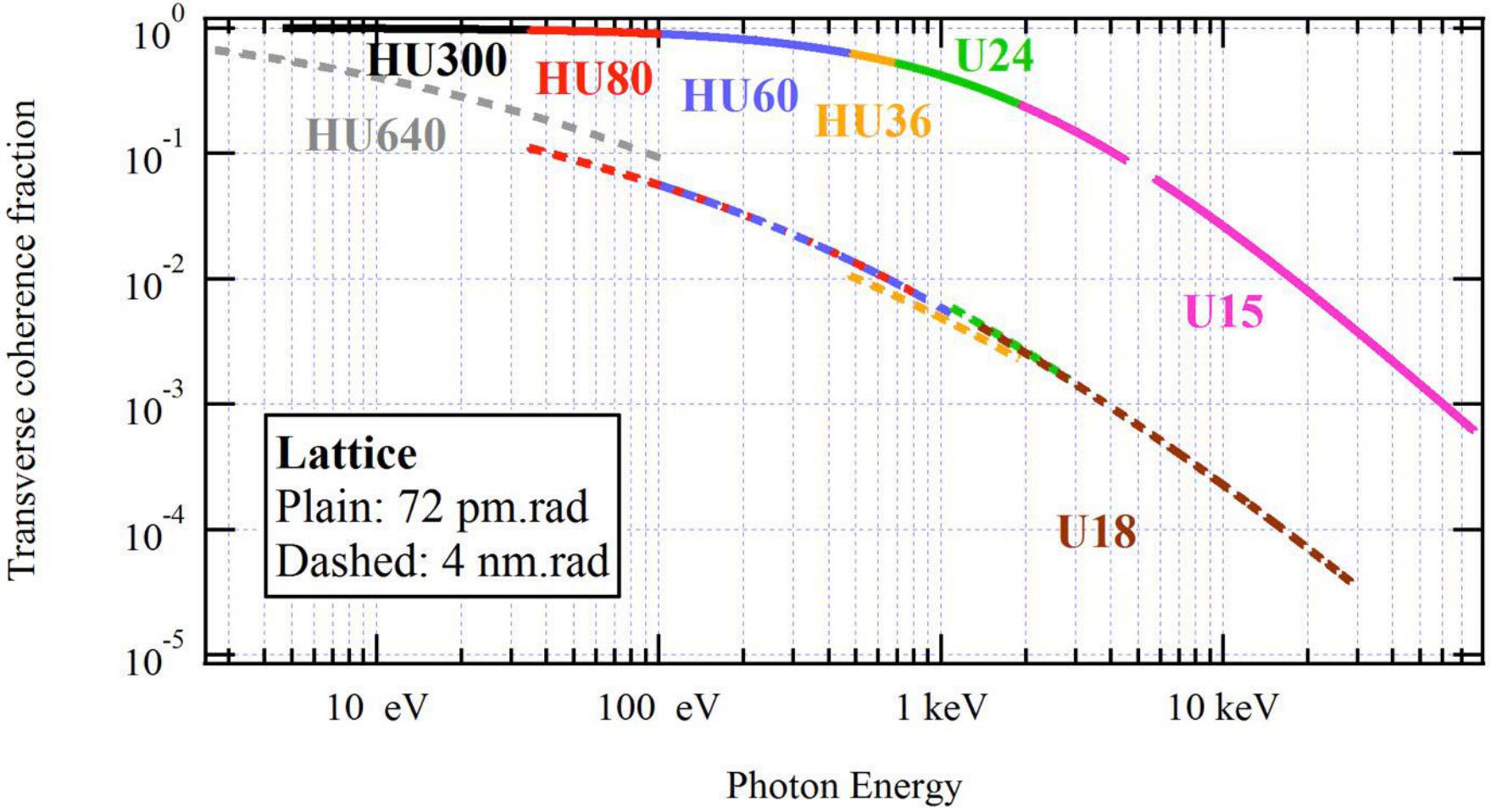


The brilliance increase reaches two orders of magnitude in the region of interest:

Between **1 to 3 keV**, exceeding a value of 10^{22} photons/s/mm2/mrad2/0.1%b.w

It can still exceed $\mathbf{10^{20}}$ photons/s/mm2/mrad2/0.1%b.w at **40 keV**!

Transverse Beam Coherence

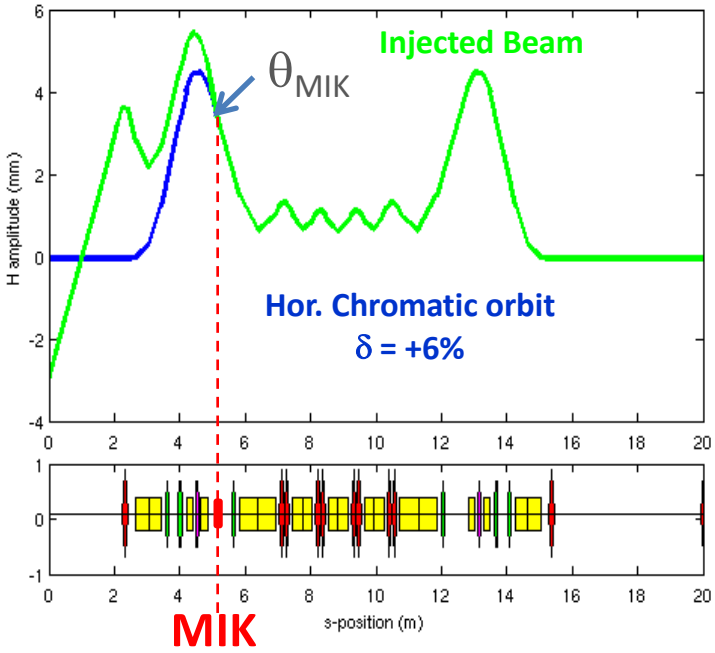


The photon beam should be **fully coherent** up to **almost 200 eV**, exceeding **40%** at **1 keV** and reaching **14%** at **3 keV**

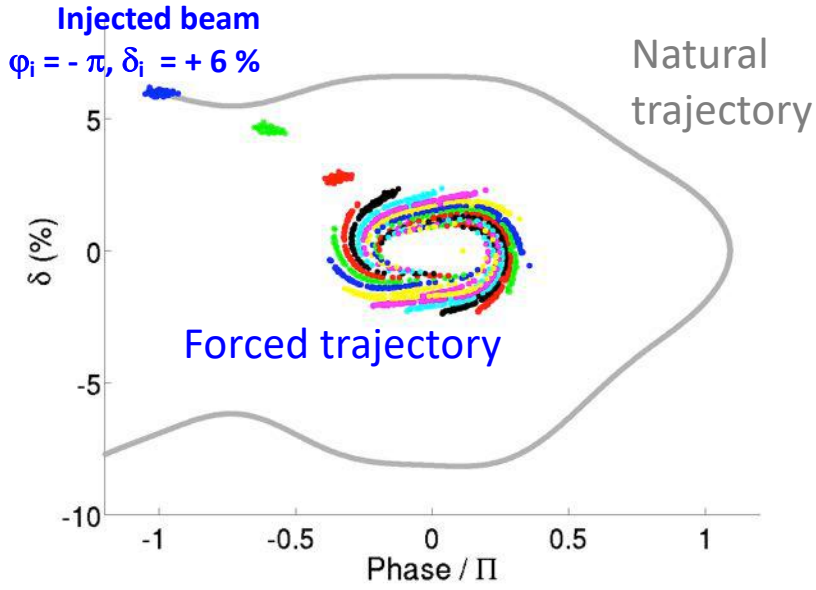
Longitudinal Injection on Chromatic Orbit with a NLK and an Extra Transient RF Pulse

Derived from :
M. Aiba et al., Longitudinal injection scheme using short pulse kicker for small aperture electron storage rings, Phys. Rev. ST Accel. Beams 18, 020701 (2015).

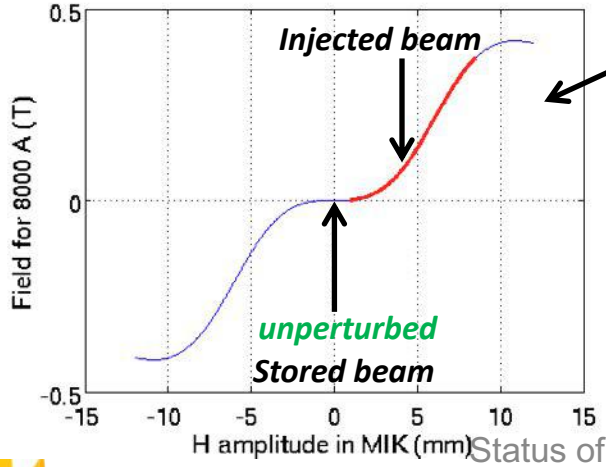
A beam with energy offset is put on chromatic **axis** with **NLK (Multipole Injection Kicker)** …



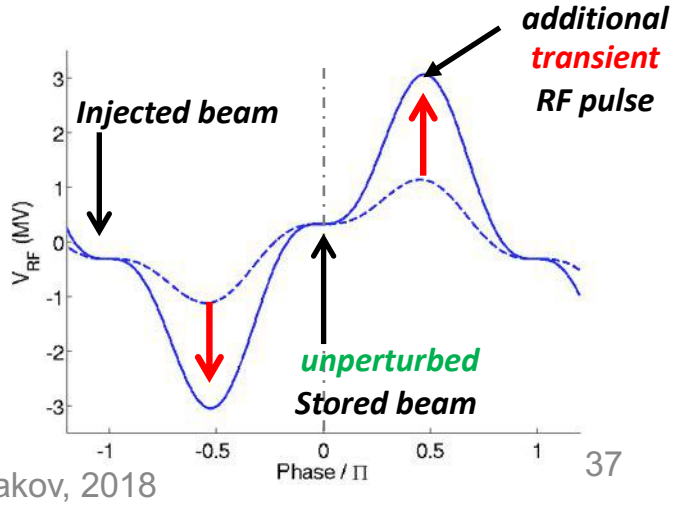
… and launched from an offset phase (**- π**), its energy is damped thanks to **a transient RF pulse** (main and harmonic)



Field profile for **Transverse NLK (MIK)**



Voltage profile for **Longitudinal NLK (RF)**



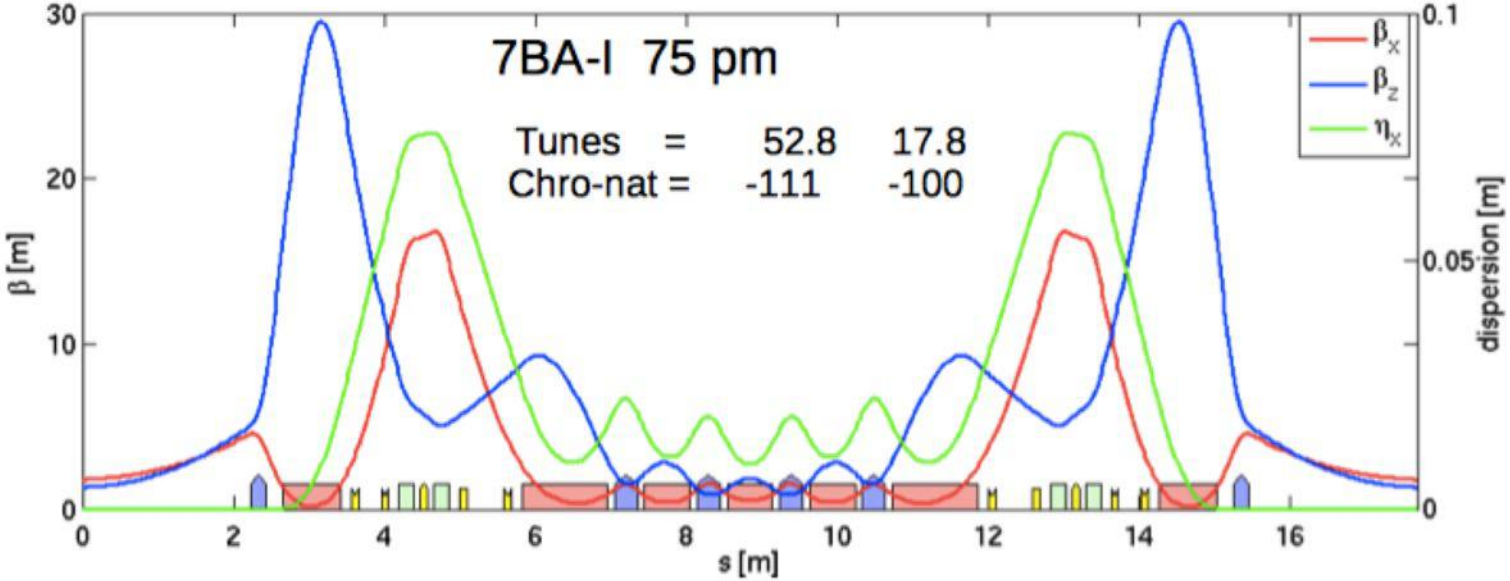
Booster emittance of **30 nm.rad** **gives 100 % efficiency** on a perfect baseline lattice

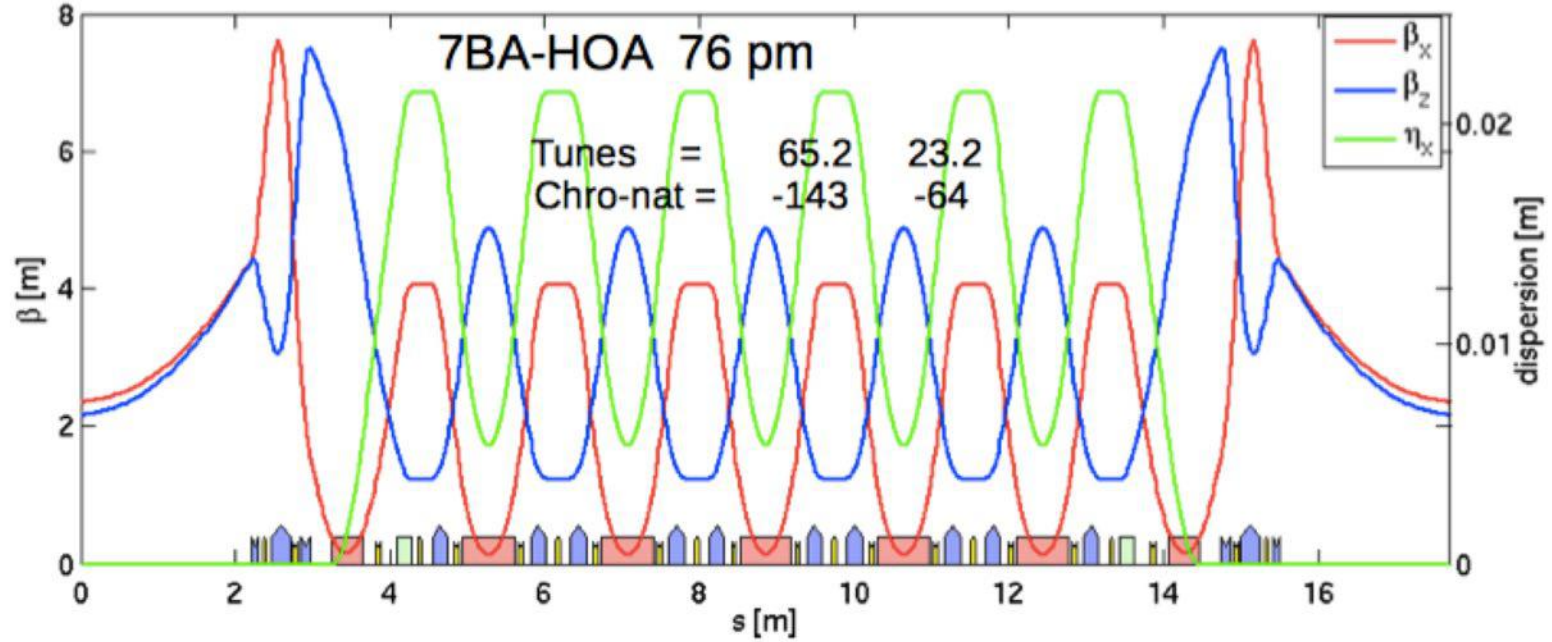
- **Breaking the symmetry 20 (Straight Section of 4.4m)**
  - Solution with Symmetry 4: **75 pm.rad**
  - Accommodating **6 m/4 m** straight sections
  - **Included canted in-vacuum undulators**

- **Preserving the low emittance**: 74 pm.rad
  - High Order Achromat to third order: 7BA-HOA lattice

LATTICE ALTERNATIVES

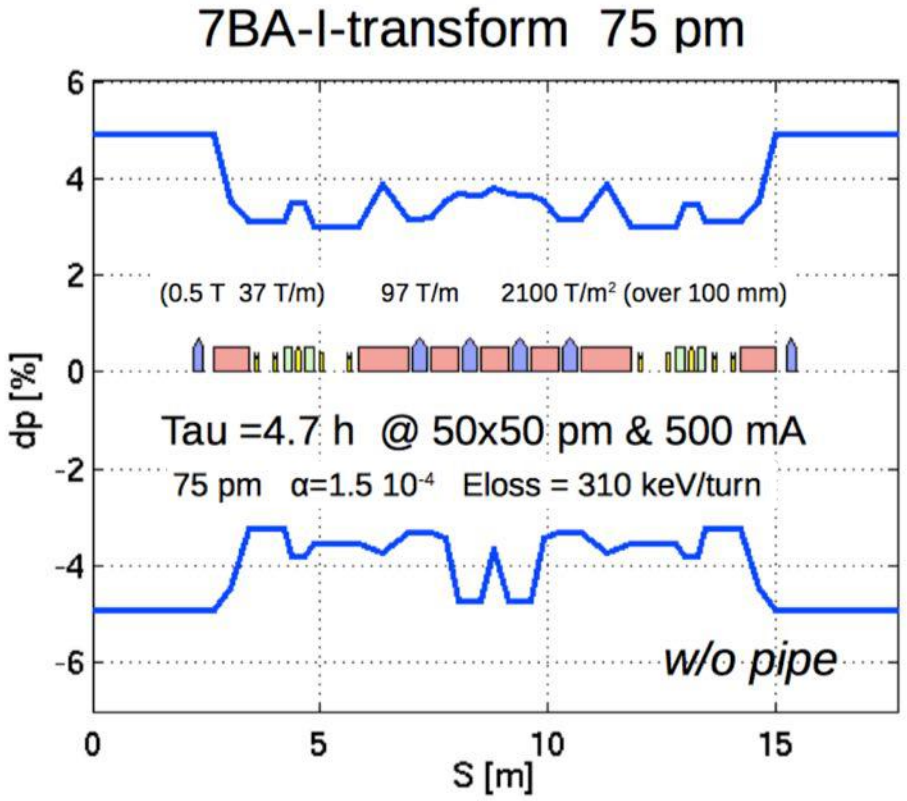
7BA-HOA lattice option

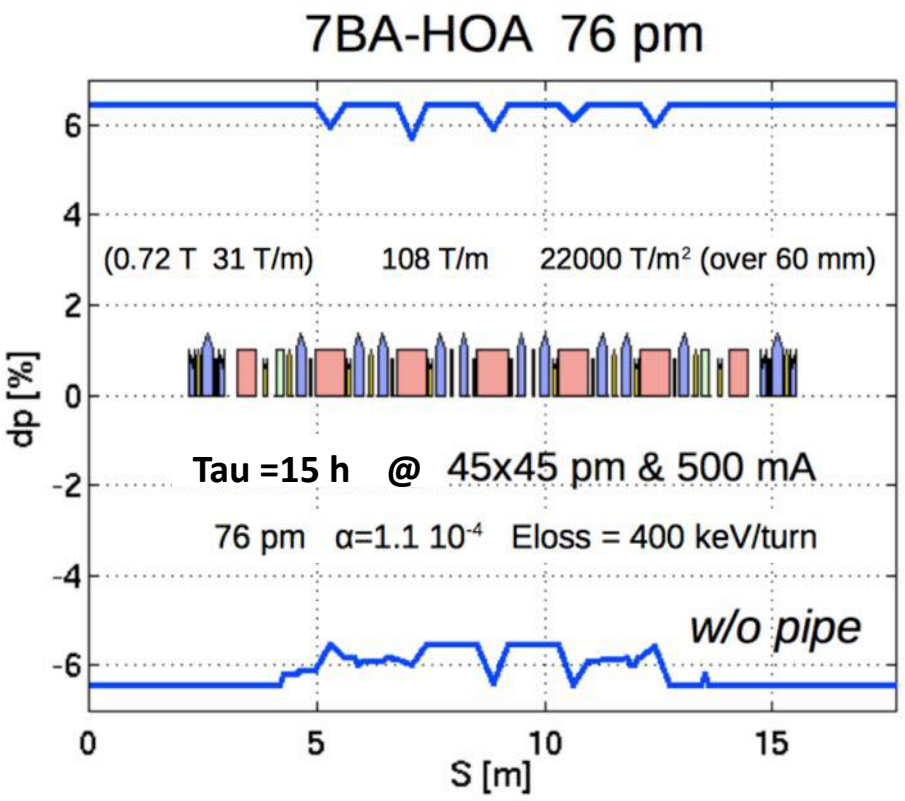




Following ALS work by S. Leemann doi:10.18429/JACoW-IPAC2018-THPMF077

Momentum Acceptance





$\sigma_s = 3.7 \ mm$
$V_{rf} = 1.1 \ MV$
$\phi_s = 0.28 \ rad$

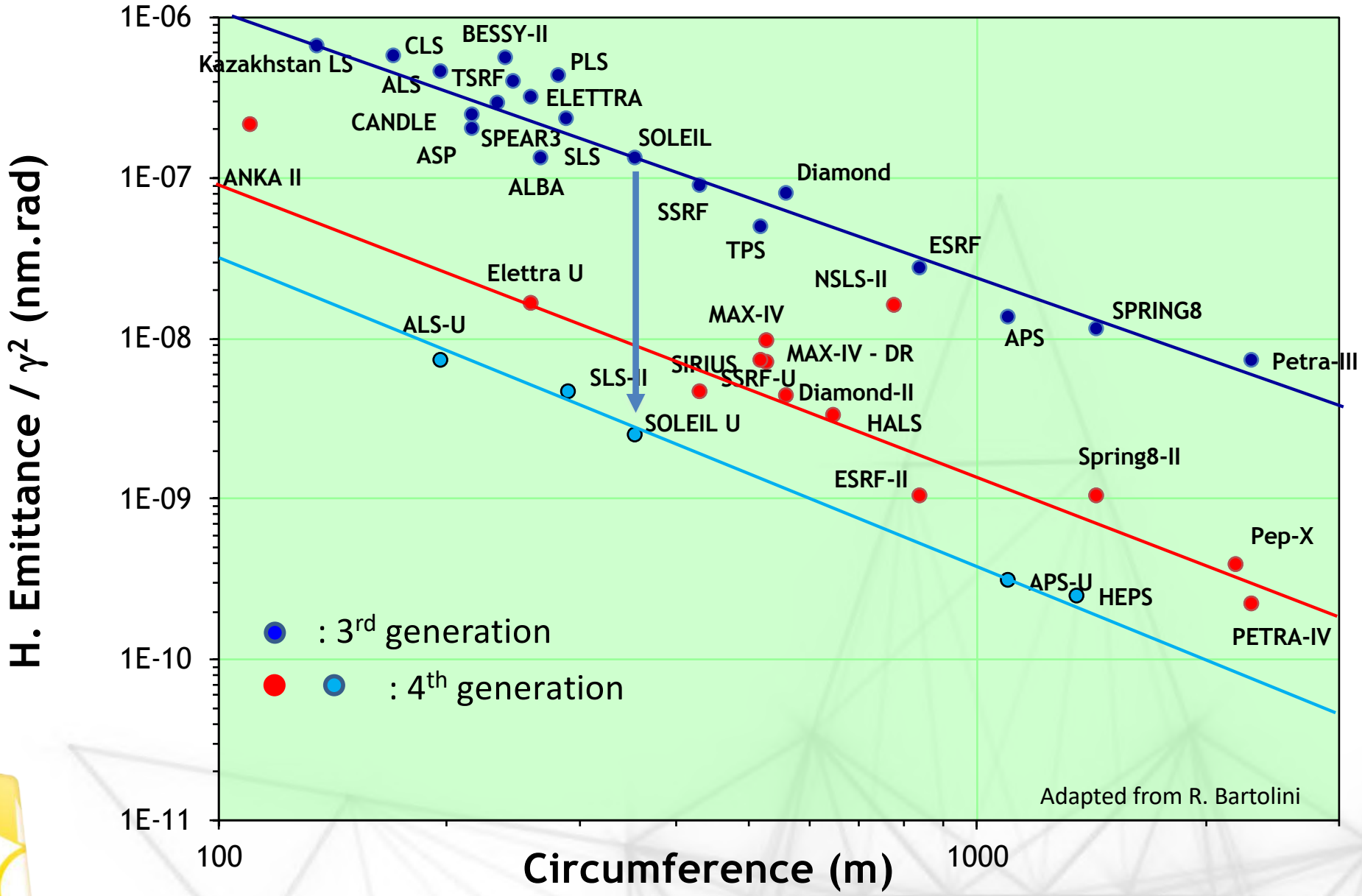
$\sigma_s = 2.5 \ mm$
$V_{rf} = 1.4 \ MV$
$\phi_s = 0.28 \ rad$

Beam lifetime computed at **full coupling** and **0 current bunch length** **w/o HC** lengthening

Lattice Parameters for a 2.75 GeV Energy

Parameters (Bare lattice)	TODAY	Baseline	Option2
Emittance H (pm•rad)/ round	3900	72/50	77/45
Circumference (m)	354.1	350.2	350.2
Lattice Type	DBA	7BA -I	7BA HOA
Cell Number	16	20	20
Symmetry	4 (1)	20 (4,1)	20 (4,1)
Betatron Tunes	18.20 / 10.30	54.3/18.3	65.2/23.2
Natural Chromaticies	-53/-19	-120/-127	-142/-64
Momentum Compaction α1	4.5×10^{-4}	1.5×10^{-4}	1.09×10^{-4}
Energy Loss per Turn (keV)	900	300	400
Energy spread	1.016×10^{-3}	0.780×10^{-3}	0.776×10^{-3}
Operating coupling, εV/εH	1%	100%	100%
Touschek Lifetime (h) @ 500 mA	14	15 (w/ 3HC)	60 (w/ 3HC)
Total Lifetime (h) @ 500 mA	36	10	20
Injection Scheme	H-plane Off-axis 4 kickers	L-plane NLK + L-NLK	L-plane NLK + L-NLK

3rd and 4th Generation Storage Ring Emittance Plot



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A Tentative Schedule for An Upgrade

Positive signs from funding agencies, asking for details in terms of budget and future performance. **R&D prototyping starts in 2019-2020**

Date	Phase
Dec. 2016	Council meeting, presentation of the first proposal for an upgrade.
2017 - 2019	Discussions regarding the definition of the project (beamlines and storage ring); definition of objectives. Baseline Lattice defined.
2018 - 2019	Continuation of discussions and prototyping to assess feasibility of key options.
2019	**Decision to launch a Conceptual Design Report (CDR).**
2019-2020	CDR based on preliminary studies and prototyping.
2020	**Decision to launch a Technical Design Report (TDR).**
2020-2022	Technical Design Report.
2022	**Decision to start the project.**
2022-2025	Reconstruction of storage ring and beamlines.
2026	Restart of user operation.

Conclusion on the upgrade part

- The present SOLEIL upgrade lattice baseline achieve a low natural emittance of **72 pm.rad** or 50 x 50 pm.rad at full coupling.
- Low beta function at the center of straight section for a good electron-photon beam matching up enabling a very high brilliance (> 10^{22} photons/s/mm^2/mrad^2/0.1%b.w.) in the **1 to 3 keV region**.
- The use of a Transverse NLK (MIK) allows to inject an **off-momentum beam ON (chromatic) AXIS**. Unlike swap-out injection method, this does not require very fast kicker, but a **'slow' MIK**.
- Other lattice variants are under study allowing the implementation of **canted in-vacuum undulators and better beam lifetime**.
- The quest of the grail is to find a lattice giving the same performances and minimizing the impact on the implementation of the beamlines.

Towards a Brighter Future

Questions ?