

14-15 DECEMBER 2022 | GRENOBLE, FRANCE

# ESLS 2022

*European Synchrotron  
Light Source Workshop*



# SOLEIL: Operation, Upgrade Status and Economy Plan

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on behalf of the Accelerators and  
Engineering Division

- SOLEIL
  - Main Performance
  - Main Achievements
  - Project Update
- Energy Saving Plan
- THOMX and COXINEL Major Results
- SOLEIL II update
  - TDR phase
  - Lattice Update
  - Prototypes Overview







# Third Generation Light Source

Location: France, 11 km South of Paris

Circumference: **354 m**

**24** straight sections

(variable length)

SDL: 4 x **12 m**

SDM: 12 x **7 m**

SDC: 8 x **3.6 m**

**29** beamlines

- 2 IR
- 7 on bending magnets
- 20 on insertion devices

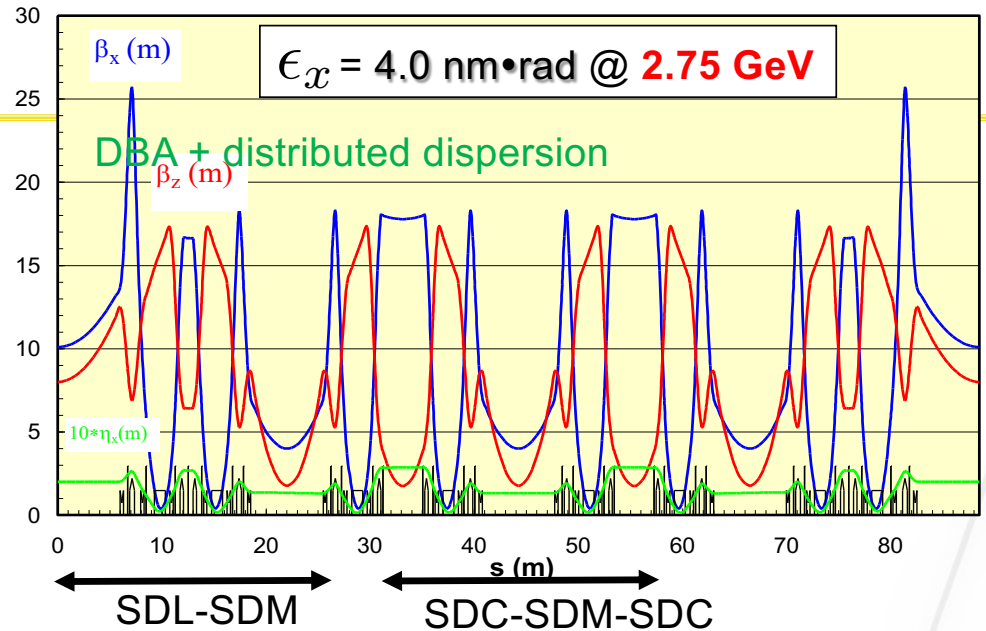
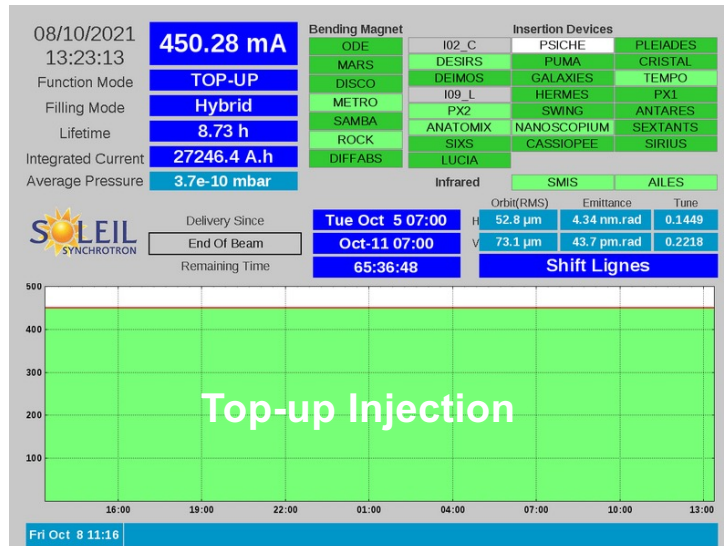


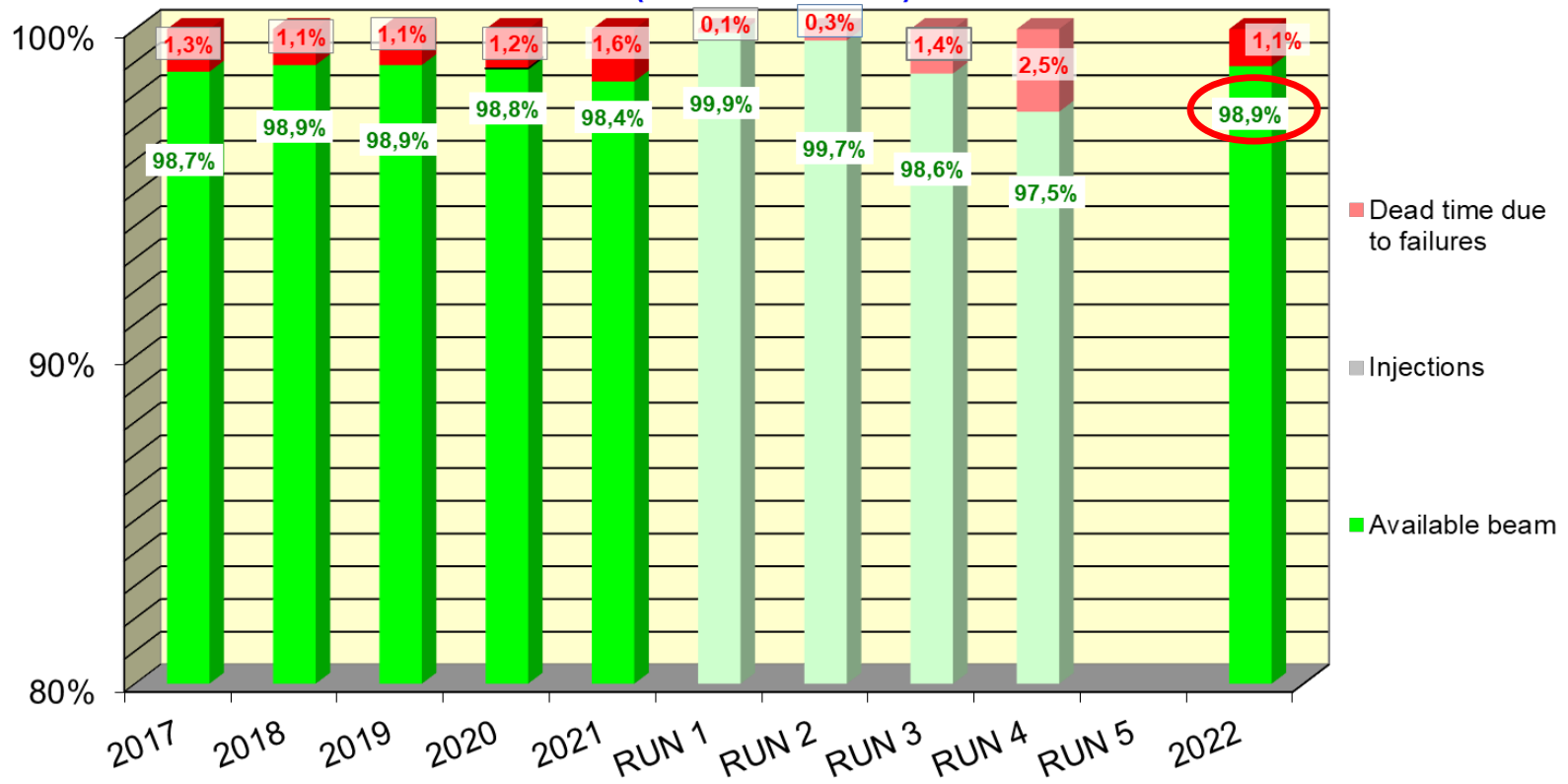
Table 1: Storage Ring Main Parameters

Parameters	Values
Energy	2.75 GeV
Circumference	354.097 m
Natural chromaticities (H/V)	-53/-19
Natural Emittance	4.0 nm · rad
Number of Cells/Symmetry	16/1
Tunes (H/V)	18.155 / 10.229
RF frequency (harmonic number)	352.197 MHz (416)
Total RF Voltage	2.8 MV

ESLS2022, ESRF, December 14-15, LSN

# User Photon Beam Availability

Efficiency during beamlines and RP sessions in 2022  
**3971 hours** of beamtime delivered  
 represent a beam availability of **98,9 %**  
 (RUN1 to RUN 4)

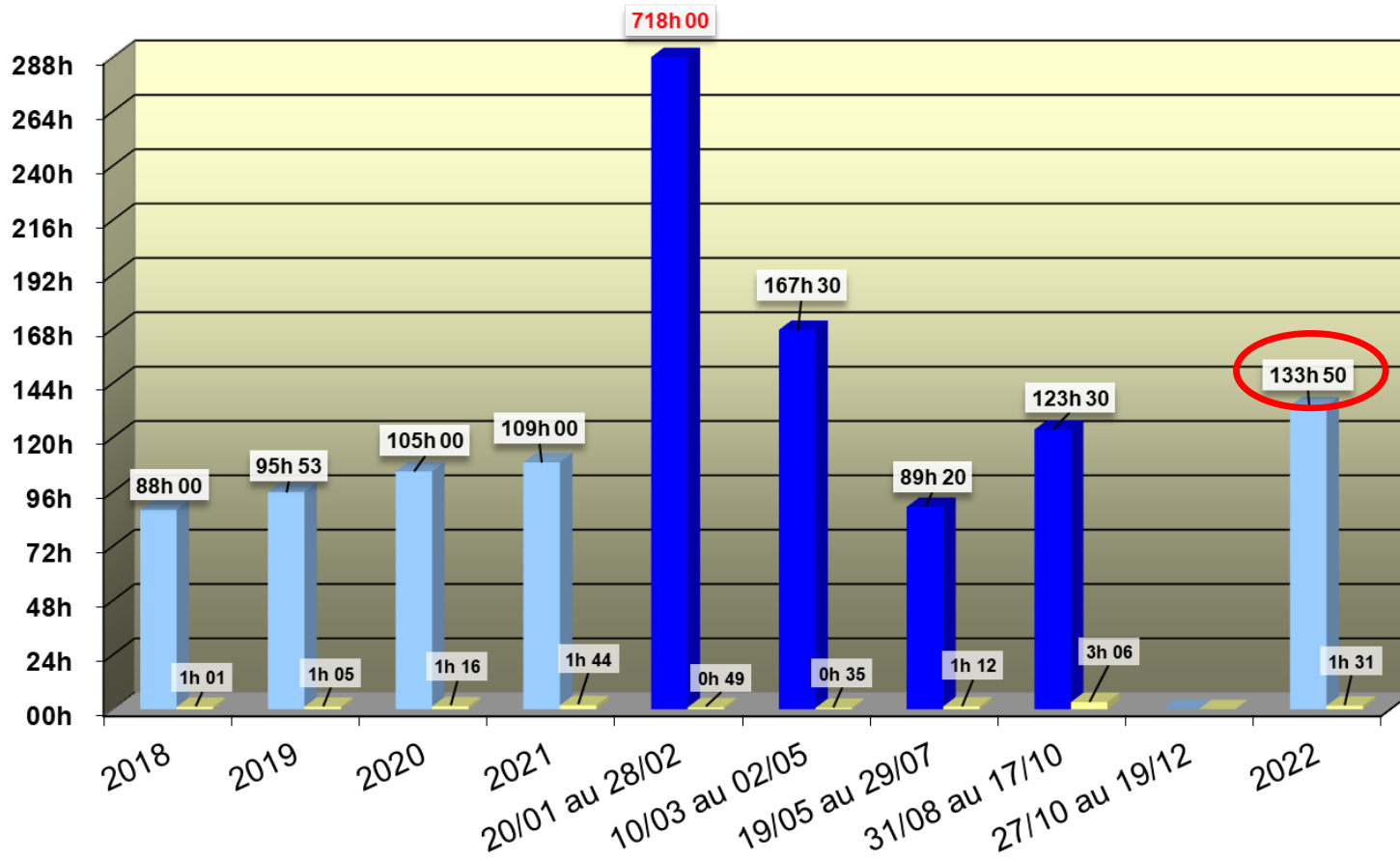


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# Mean Time Between Failure

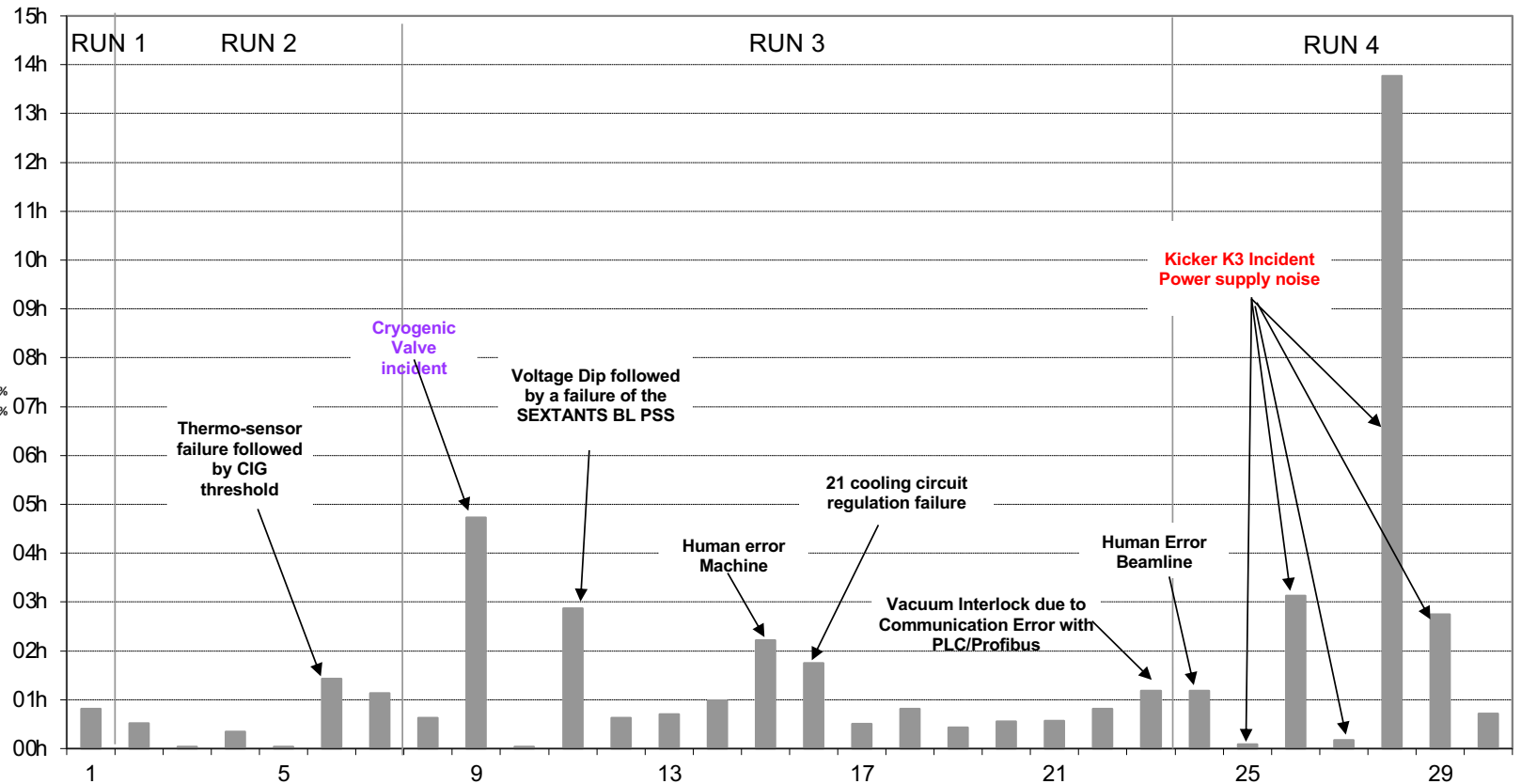
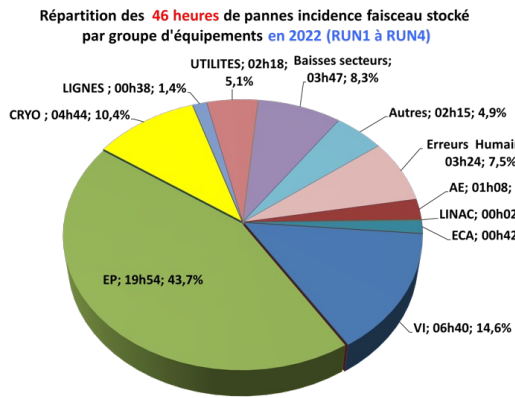
**2022 (RUN1 to RUN4): 133 hours**



# RUN1 to RUN 4 2022

## Duration of the 30 beam Interruptions

Total 45:32  
 Min 00:02  
 Max 13:46  
 Mean 01:31  
 RMS 02:33



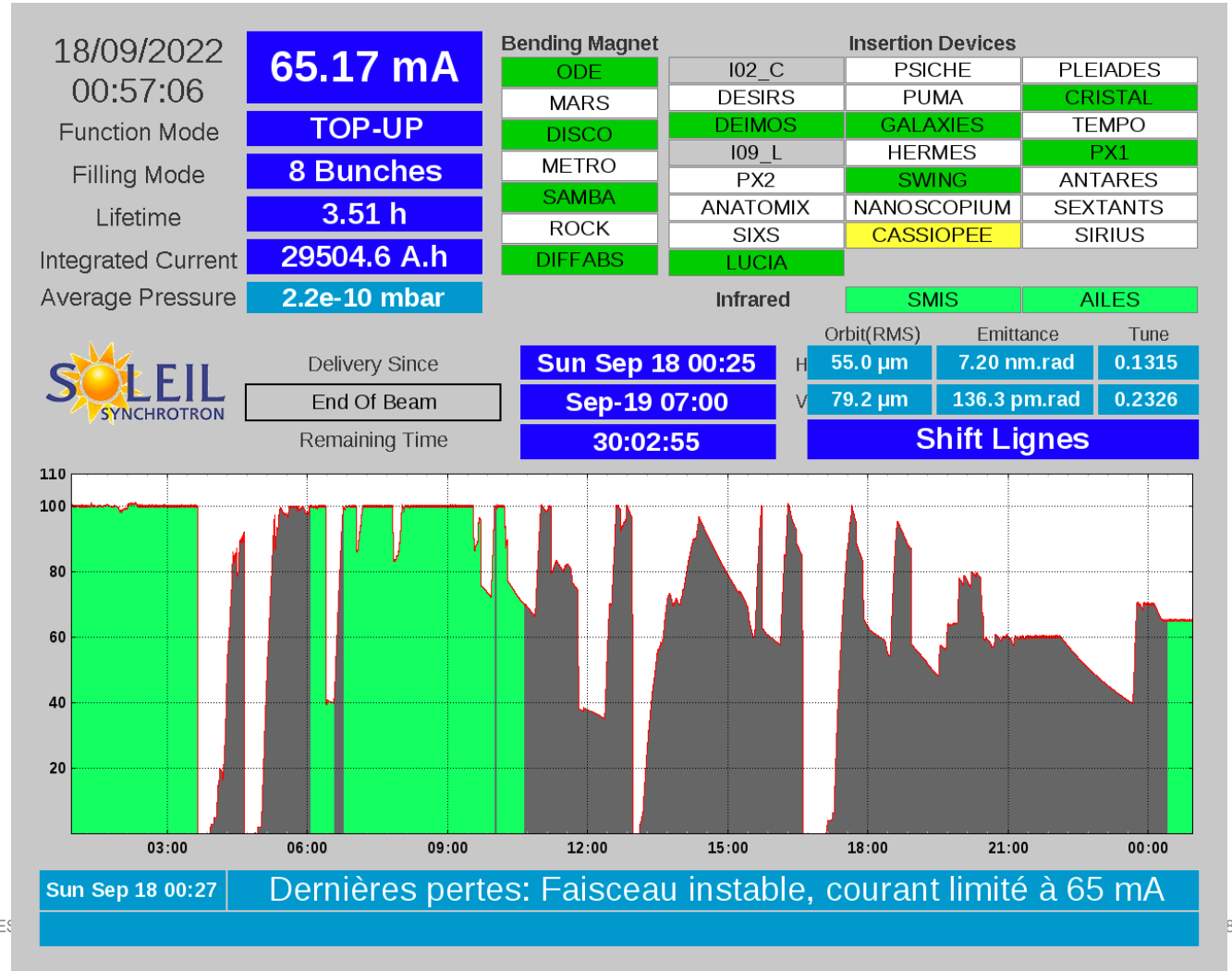
# A Very Difficult Day: a Noisy (Random) Injection kicker

A long and very subtle failure on one of the injection kickers which made us lose 19 hours on Saturday 17/09 during a User session in 8 bunch filling pattern.

First incident of this kind since 2006

## Learnt lesson

- Loss of experience
- Continuous training
- Reinforcing postmortem capability for partial beam losses



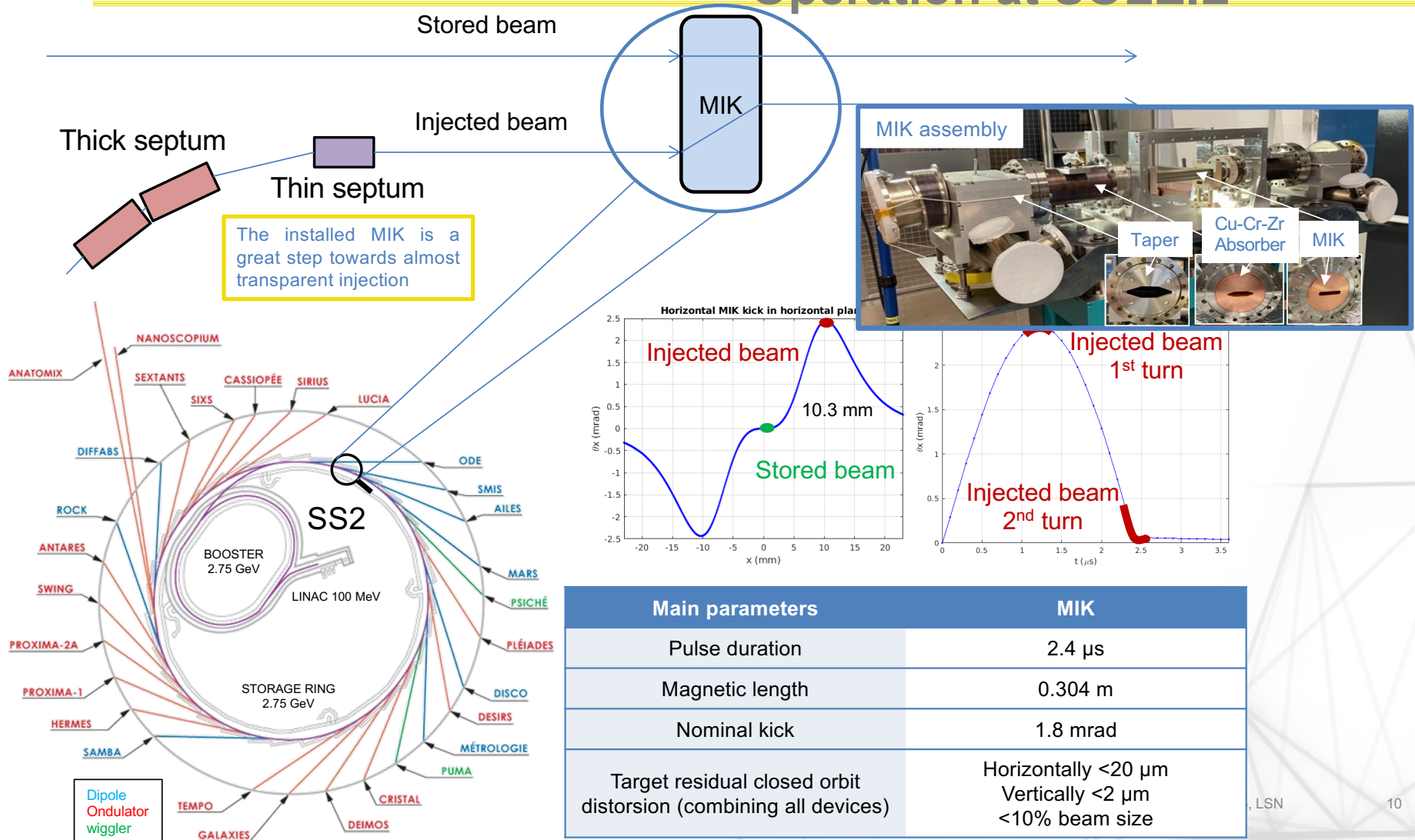


# A Selection of Major Projects



# Off-axis MIK Injection Layout for Top-Up Operation at SOLEIL

As a key element for making a compact injection scheme.



# Towards Transparent and Reliable Injection

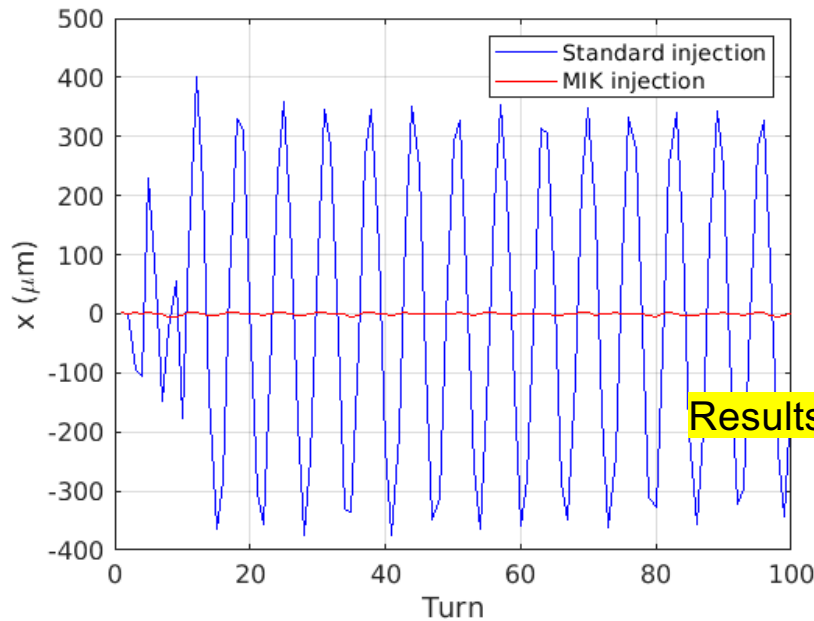
Randy Ollier PhD  
December 13, 2022

Maximum injection efficiency measured 97%

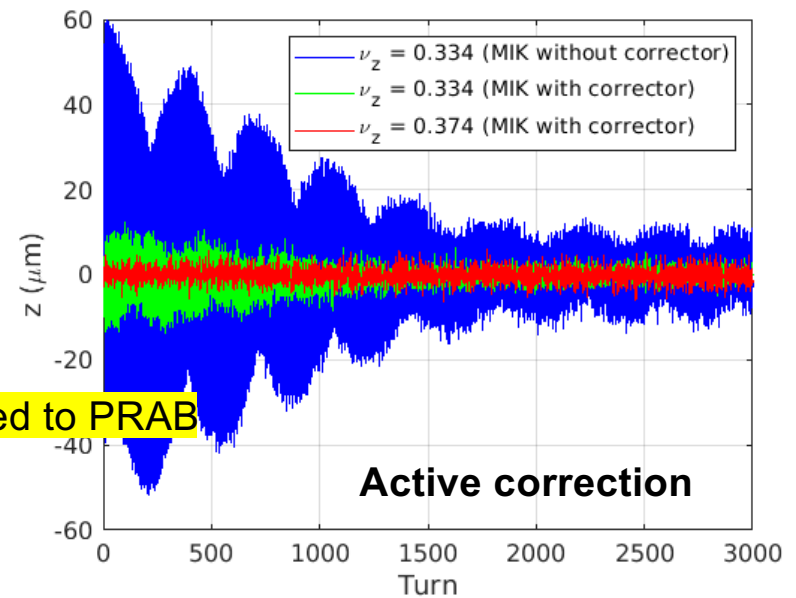
Position perturbations < 2%  $\sigma_{x,z}$  (including active correction)

$$\Delta\sigma_x = 3.5\% \text{ of } \sigma_x$$

Turn-turn High performance Diagnostics  
BLM, Brilliance+ Libera, Kalypso Camera



H-plane



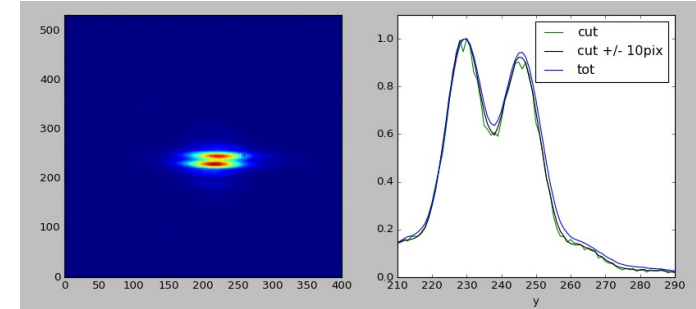
V-plane

Results submitted to PRAB

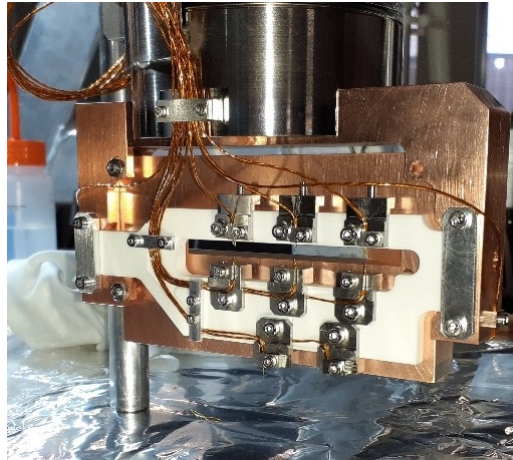
Active correction

# Visible Mirror Upgrade for New Optical Diagnostics

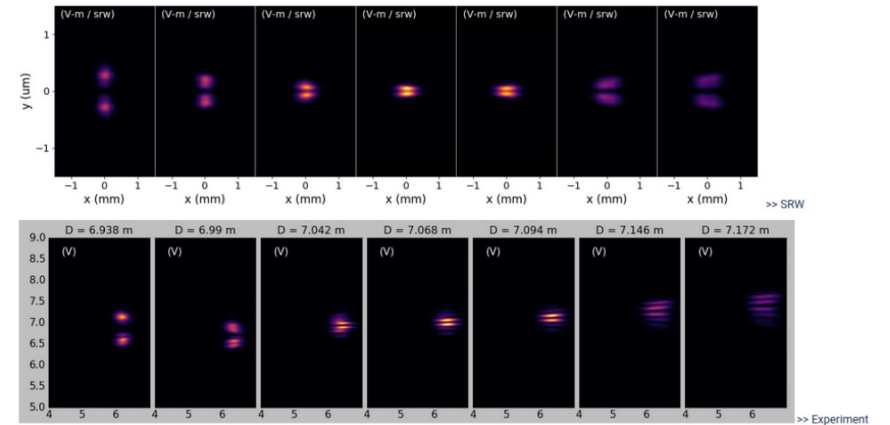
Next extraction mirror with a new extraction **slit mirror** equipment and a **more efficient cooling system**: the collected photon flux is increased by more than a factor of 2. This diagnostic beamline is now being used to commission innovative equipment like the **turn-by-turn Kalypso Camera** and **high resolution beamsize measurement** using **polarization** in preparation for the SOLEIL II



Size measurement from the vertical polarization of the photon beam from a bending magnet ( $\lambda = 400 \text{ nm}$ )



Slit mirror for the diagnostics beamline  
Test bed for new diagnostics in the frame of the upgrade

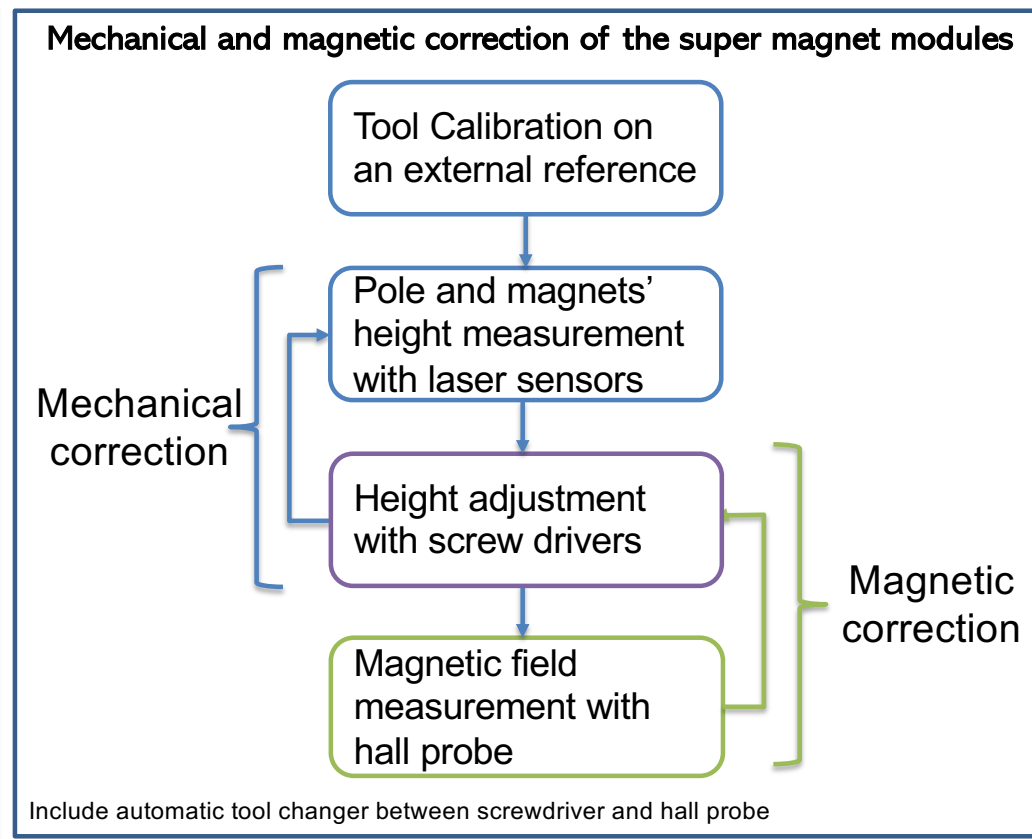
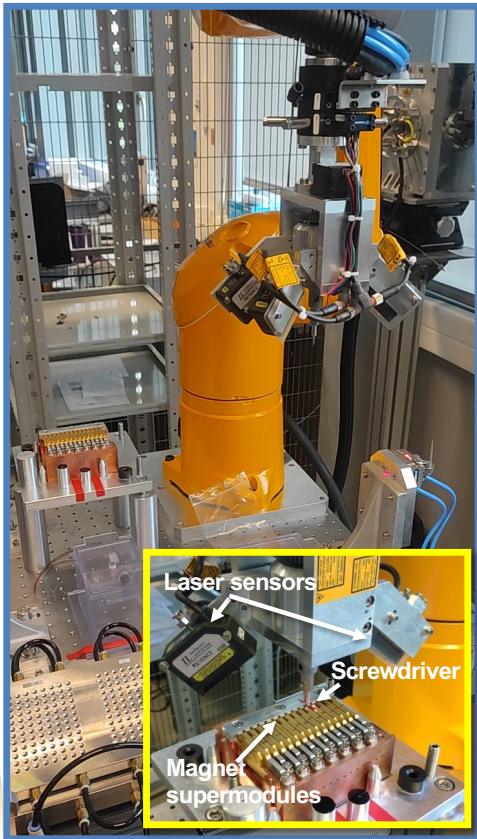


Very good agreement between simulated (top) and measured (bottom) images as a function of lens-camera distance in vertical polarization  $\theta_x = 3.5 \text{ mrad}$ ,  $\lambda = 400 \text{ nm}$ .

# Robotizing Magnet Modules Measurement Bench for Insertion Devices

- **Robotization:** part of a roadmap for machine and beamlines. Based on STAUBLI robots standardized in 2019.
- **Included in global automation strategy** under development in IT and Data management program.
- Measurement bench complementary from the one developed in 2021.

Under development !



# Major Achievements

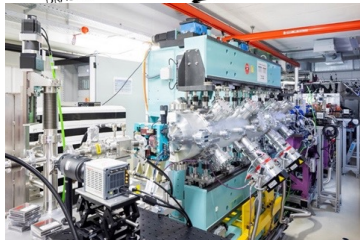
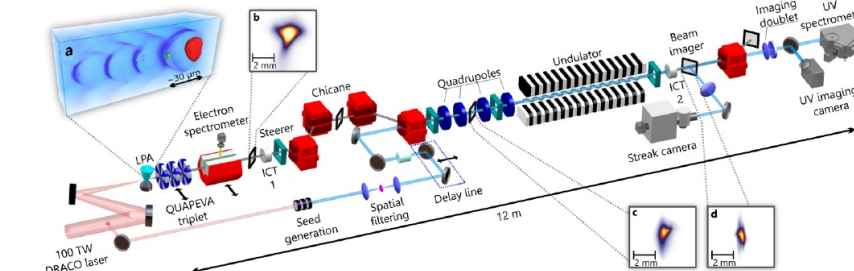


# First LPA based seeded FEL: a successful French (SOLEIL) / German (HZDR) collaboration

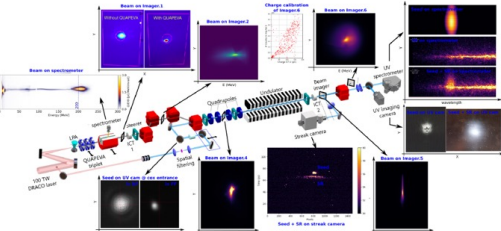
**Aim:** Demonstrate the feasibility of an LPA based seeded FEL in the UV range

Experimental setup:

- >> The high-performance Laser Plasma Accelerator of HZDR (Germany)
- >> The versatile COXINEL beamline of SOLEIL (France)



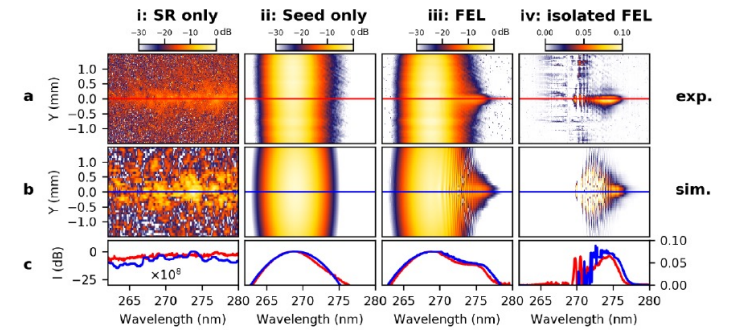
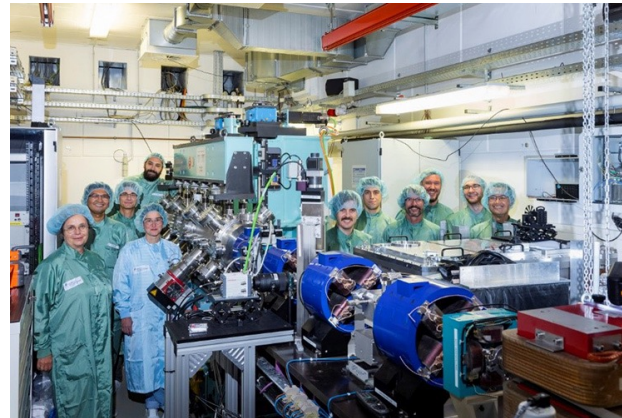
Installation of COXINEL @ HZDR: November 2021



ESLS2022, ESRF, December 13-15, 2021  
Full commissioning of beamline : December 2021

Results:

- >> Demonstration of an LPA based seeded FEL @274 nm
- >> Spectral control of the FEL wavelength
- >> Achievement of temporal coherence



M. Labat et al., Nature Photonics (2022)  
<https://doi.org/10.1038/s41566-022-01104-w>

Perspectives:

- >> Full optimization of the present configuration
- >> Operation @ 1 Hz
- >> Operation at shorter wavelength



## A compact light source based on Compton Back Scattering

Electron beam (nominal)

- Energy: 50 (70) MeV
- Charge: 1 nC (1 bunch)
- Transv. emittance: 5 pi mm mrad

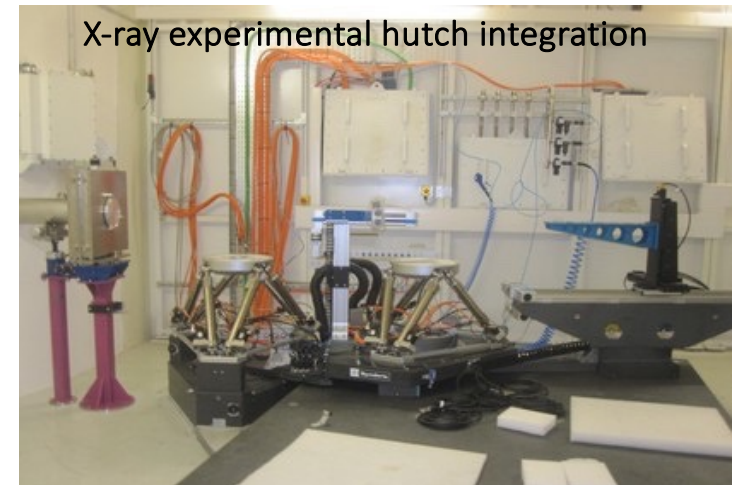
✓ 19 May 2021 Phase I authorization from French Nuclear Safety Authority Linac (E = 50 MeV, Freq = 10 Hz, Charge = 100 pC)

✓ 29 July 2022 => Phase II authorization from French Nuclear Safety Authority Linac + Transfer Line + Ring + Extraction Line



First X-rays are expected during 2023

ThomX: 45-90 keV  
 Flux ~  $10^{12}$  -  $10^{13}$  ph/s  
 Brill ~  $10^{10}$  -  $10^{11}$  unit



ESLS2022, ESRF, December 14-15, LSN

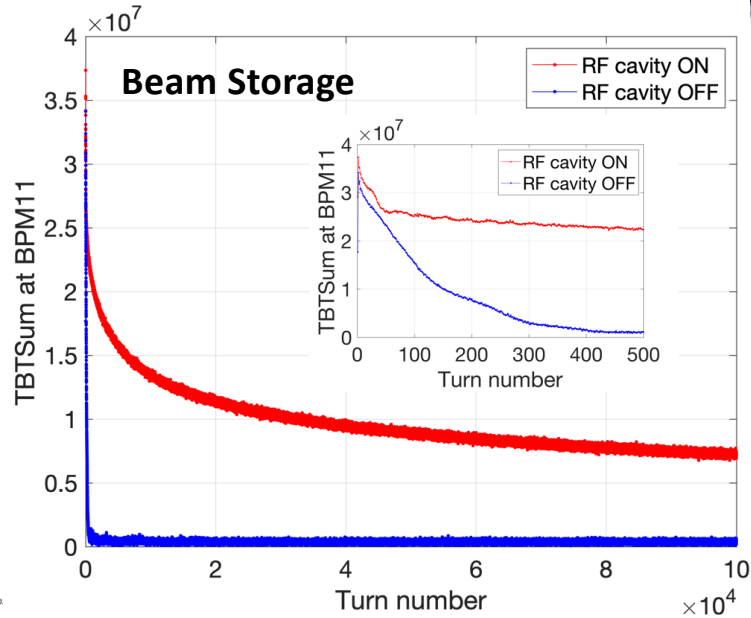
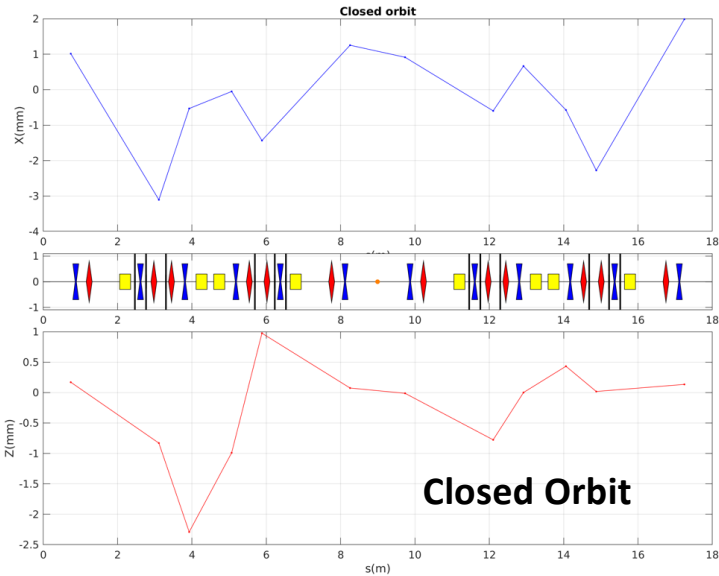
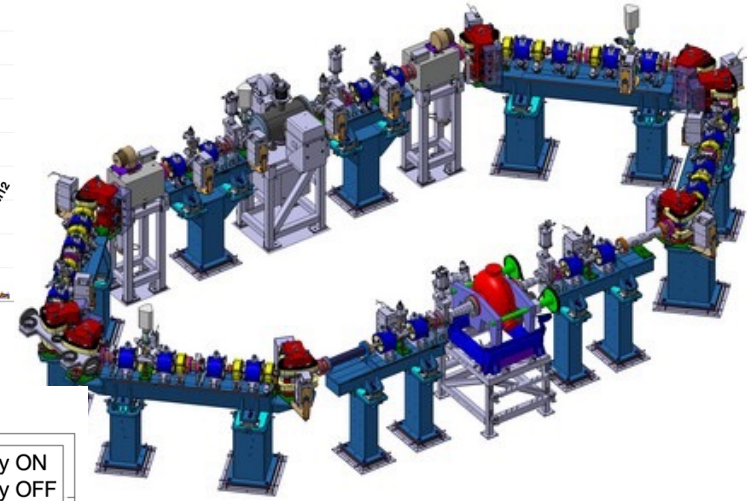
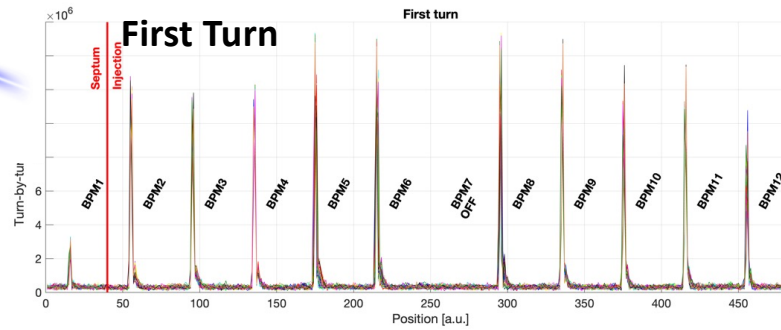
16





ThomX Ring:  $L = 18\text{ m}$ ,  $T = 60\text{ ns}$ ,  $Frep = 16.7\text{ MHz}$

- Injection + threading (19 Sept. 2022)
- First Turns  $\sim 300$  turns (3 Oct. 2022)
- Storage with RF cavity  $> 200k$  turns (8 Dec. 2022)



# Energy Saving



# 2022 Beam Schedule

Modification of the mode of operation for the last week of the year (from Low Alpha to Uniform mode)

janv 2022	févr 2022	mars 2022	avr 2022	mai 2022	juin 2022	juil 2022	août 2022	sept 2022	oct 2022	nov 2022	déc 2022	janv 2023	févr 2023
sam 01		mar 01	ven 01	dim 01	mer 01	ven 01	lun 01	jeu 01	sam 01	mar 01	jeu 01	dim 01	mer 01
dim 02		mer 02	sam 02	lun 02	jeu 02	sam 02	mar 02	ven 02	dim 02	mer 02	ven 02	lun 02	jeu 02
lun 03		jeu 03	dim 03	mar 03	ven 03	dim 03	mer 03	sam 03	lun 03	jeu 03	sam 03	mar 03	ven 03
mar 04		ven 04	lun 04	mer 04	sam 04	lun 04	jeu 04	dim 04	mar 04	ven 04	dim 04	mer 04	sam 04
mer 05	01	sam 05	mar 05	jeu 05	dim 05	mar 05	ven 05	lun 05	mar 05	sam 05	lun 05	mer 05	dim 05
jeu 06		dim 06	mer 06	ven 06	lun 06	mer 06	sam 06	jeu 06	mar 06	dim 06	mer 06	ven 06	dim 06
ven 07		lun 07	jeu 07	sam 07	mar 07	jeu 07	dim 07	mer 07	ven 07	lun 07	mer 07	sam 07	mar 07
sam 08		mar 08	ven 08	dim 08	mer 08	jeu 08	ven 08	lun 08	sam 08	mar 08	jeu 08	dim 08	mer 08
dim 09		mer 09	lun 09	mer 09	jeu 09	sam 09	lun 09	ven 09	dim 09	mer 09	ven 09	dim 09	jeu 09
lun 10		jeu 10	dim 10	mar 10	ven 10	dim 10	mer 10	sam 10	lun 10	jeu 10	sam 10	mar 10	ven 10
mar 11		ven 11	lun 11	mer 11	sam 11	lun 11	jeu 11	dim 11	mar 11	ven 11	dim 11	mer 11	sam 11
mer 12		sam 12	mar 12	jeu 12	dim 12	mar 12	ven 12	lun 12	mar 12	sam 12	lun 12	mer 12	dim 12
jeu 13	02	dim 13	mer 13	ven 13	lun 13	mer 13	sam 13	jeu 13	mar 13	dim 13	mer 13	ven 13	lun 13
ven 14		lun 14	jeu 14	sam 14	mar 14	jeu 14	dim 14	mer 14	ven 14	lun 14	mer 14	sam 14	mar 14
sam 15		mar 15	ven 15	dim 15	mer 15	jeu 15	ven 15	lun 15	sam 15	mar 15	jeu 15	dim 15	mer 15
dim 16		mer 16	lun 16	mer 16	jeu 16	sam 16	lun 16	ven 16	dim 16	mer 16	ven 16	dim 16	jeu 16
lun 17		jeu 17	dim 17	mar 17	ven 17	dim 17	mer 17	sam 17	lun 17	jeu 17	sam 17	mar 17	ven 17
mar 18		ven 18	lun 18	mer 18	sam 18	lun 18	jeu 18	dim 18	mar 18	ven 18	dim 18	mer 18	sam 18
mer 19	03	sam 19	mar 19	jeu 19	dim 19	mar 19	ven 19	lun 19	mar 19	mer 19	lun 19	jeu 19	dim 19
jeu 20	A A A	dim 20	mer 20	ven 20	lun 20	mer 20	sam 20	jeu 20	mar 20	dim 20	mer 20	ven 20	lun 20
ven 21	A A A	lun 21	jeu 21	sam 21	mar 21	jeu 21	dim 21	mer 21	ven 21	lun 21	mer 21	sam 21	mar 21
sam 22	A A A	mar 22	ven 22	dim 22	mer 22	jeu 22	ven 22	lun 22	sam 22	mar 22	jeu 22	dim 22	mer 22
dim 23	A A A	mer 23	lun 23	mer 23	jeu 23	sam 23	lun 23	ven 23	dim 23	mer 23	ven 23	lun 23	jeu 23
lun 24	A A A	jeu 24	dim 24	mar 24	ven 24	dim 24	mer 24	sam 24	lun 24	jeu 24	sam 24	mar 24	ven 24
mar 25	B B B	ven 25	lun 25	mer 25	sam 25	lun 25	jeu 25	dim 25	mar 25	ven 25	dim 25	mer 25	sam 25
mer 26	U U U	sam 26	mar 26	jeu 26	dim 26	mar 26	ven 26	lun 26	mar 26	jeu 26	sam 26	mer 26	dim 26
jeu 27	U U U	dim 27	mer 27	ven 27	lun 27	mer 27	sam 27	jeu 27	mar 27	dim 27	mer 27	ven 27	lun 27
ven 28	U 04	lun 28	jeu 28	sam 28	mar 28	jeu 28	dim 28	mer 28	ven 28	lun 28	mer 28	sam 28	mar 28
sam 29	U U U	mar 29	ven 29	dim 29	mer 29	jeu 29	ven 29	lun 29	jeu 29	mar 29	jeu 29	dim 29	mer 29
dim 30	U U U	mer 30	lun 30	mer 30	jeu 30	sam 30	lun 30	ven 30	dim 30	mer 30	ven 30	lun 30	jeu 30
lun 31	A A Tv	jeu 31	lun 31	mar 31	jeu 31	dim 31	mer 31	ven 31	lun 31	mar 31	sam 31	mar 31	jeu 31

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

Version validée par la RD et le CSE (28/10/2021)  
 MaJ du 12/05/2022 (semaine Low-Alpha en fin d'année)  
 Users meeting du 20 et 21 janvier 2022  
 Ecole HERCULES du 21-25 mars 2022  
 Congés scolaires zone C

Energy saving  
 Machine Test  
 21° → 23 °C



# 2023 Beam Schedule



## Calendrier de fonctionnement 2023

janv 2023		févr 2023		mars 2023		avr 2023		mai 2023		juin 2023		juil 2023		août 2023		sept 2023		oct 2023		nov 2023		déc 2023		janv 2024		févr 2024	
dim 01		mer 01	.05	mer 01	.09	sam 01	M M M	lun 01		jeu 01	M M M	sam 01	M M M	mar 01		ven 01	A A A	dim 01	M M M	mer 01	M M M	ven 01	M M M	lun 01		jeu 01	M M M
lun 02		jeu 02	.05	jeu 02	.09	dim 02	M M M	mar 02		ven 02	M M M	dim 02	M M M	mer 02		sam 02	A A A	lun 02	A A Tv	jeu 02	M M M	sam 02	M M M	mar 02		ven 02	M M M
mar 03		ven 03		ven 03		lun 03	A A Tv	mer 03		sam 03	M M M	lun 03	A A Tv	jeu 03	31	dim 03	A A A	mar 03	B B B	ven 03	M M M	dim 03	M M M	mer 03		sam 03	M M M
mer 04		sam 04		sam 04		mar 04	B B B	jeu 04	18	dim 04	M M M	mar 04	Cp Cp B	ven 04		lun 04	A A A	mer 04	M M M	sam 04	M M M	lun 04	A A Tv	jeu 04		dim 04	M M M
jeu 05	.01	dim 05		dim 05		mer 05	M M M	ven 05		lun 05	A A Tv	mer 05	M M M	sam 05		mar 05	B B B	jeu 05	M M M	dim 05	M M M	mar 05	B B B	ven 05		lun 05	A A Tv
ven 06		lun 06		lun 06		jeu 06	M M M	sam 06		mar 06	B B B	jeu 06	M M M	dim 06		mer 06	M M M	ven 06	M M M	lun 06	A A Tv	mer 06	M M M	sam 06		mar 06	B B B
sam 07		mar 07		mar 07		ven 07	M M M	dim 07		mer 07	M M M	ven 07	M M M	lun 07		jeu 07	M M M	sam 07	M M M	mar 07	B B B	jeu 07	M M M	dim 07		mer 07	M M M
dim 08		mer 08		mer 08	10	sam 08	M M M	lun 08		jeu 08	M M M	sam 08	M M M	mar 08		ven 08	M M M	dim 08	M M M	mer 08	M M M	ven 08	M M M	lun 08		jeu 08	M M M
lun 09		jeu 09	.06	jeu 09	.06	dim 09	M M M	mar 09		ven 09	M M M	dim 09	M M M	mer 09		sam 09	M M M	lun 09	A A Tv	jeu 09	M M M	sam 09	M M M	mar 09		ven 09	M M M
mar 10		ven 10		ven 10		lun 10	A A Tv	mer 10		sam 10	M M M	lun 10	A A Tv	jeu 10	32	dim 10	M M M	mar 10	B B B	ven 10	M M M	dim 10	M M M	mer 10		sam 10	M M M
mer 11		sam 11		sam 11		dim 11	M M M	jeu 11	19	dim 11	M M M	mar 11	B B B	ven 11		lun 11	A A Tv	mer 11	M M M	sam 11	M M M	lun 11	A A Tv	jeu 11		dim 11	M M M
jeu 12	.02	dim 12		dim 12		mer 12	M M M	ven 12		lun 12	A A Tv	mer 12	M M M	sam 12		mar 12	B B B	jeu 12	M M M	dim 12	M M M	mar 12	B B B	ven 12		lun 12	A A Tv
ven 13		lun 13		lun 13		jeu 13	M M M	sam 13		mar 13	B B B	jeu 13	M M M	dim 13		mer 13	M M M	ven 13	M M M	lun 13	A A A	mer 13	M M M	sam 13		mar 13	B B B
sam 14		mar 14		mar 14		ven 14	M M M	dim 14		mer 14	M M M	ven 14	M M M	lun 14		jeu 14	M M M	sam 14	M M M	mar 14	Cp Cp B	jeu 14	M M M	dim 14		mer 14	M M M
dim 15		mer 15		mer 15		sam 15	M M M	lun 15		jeu 15	M M M	sam 15	M M M	mar 15		ven 15	M M M	dim 15	M M M	mer 15	M M M	ven 15	M M M	lun 15		jeu 15	M M M
lun 16		jeu 16	.07	jeu 16	.07	dim 16	M M M	mar 16		ven 16	M M M	dim 16	M M M	mer 16		sam 16	M M M	lun 16	M M M	jeu 16	M M M	sam 16	M M M	mar 16		ven 16	M M M
mar 17		ven 17		ven 17		lun 17	A A Tv	mer 17	20	sam 17	M M M	lun 17	A A Tv	jeu 17	33	dim 17	M M M	mar 17	M M M	ven 17	M M M	dim 17	M M M	mer 17		sam 17	M M M
mer 18		sam 18		sam 18		dim 18	M M M	jeu 18		dim 18	M M M	mar 18	B B B	ven 18		lun 18	A A A	mer 18	M M M	sam 18	M M M	lun 18	M M M	jeu 18		dim 18	M M M
jeu 19	.03	dim 19		dim 19		mer 19	M M M	ven 19		lun 19	A A Tv	mer 19	M M M	sam 19		mar 19	B B B	jeu 19	M M M	dim 19	M M M	mar 19	M M M	ven 19	A A A	lun 19	
ven 20		lun 20		lun 20		jeu 20	M M M	sam 20		mar 20	B B B	jeu 20	M M M	dim 20		mer 20	M M M	ven 20	M M M	lun 20	A A Tv	jeu 20	M M M	dim 20		sam 20	A A A
dim 21		mar 21		mar 21		ven 21	M M M	dim 21		mer 21	M M M	ven 21	M M M	lun 21		jeu 21	M M M	sam 21	M M M	mar 21	B B B	jeu 21		dim 21	A A A	mer 21	
lun 22		jeu 22	.08	jeu 22	.08	sam 22	M M M	lun 22		jeu 22	M M M	sam 22	M M M	mar 22		ven 22	M M M	dim 22	M M M	mer 22	M M M	ven 22		lun 22	A A A	jeu 22	
mar 23		ven 23		ven 23		dim 23	M M M	mar 23		ven 23	M M M	dim 23	M M M	mer 23		sam 23	M M M	lun 23	M M M	jeu 23	M M M	sam 23	M M M	mar 23	B B B	ven 23	
mer 24		dim 24		dim 24		mer 24	M M M	ven 24		sam 24	M M M	lun 24	M M M	jeu 24	34	dim 24	M M M	mar 24	M M M	ven 24	M M M	dim 24		mer 24	M M M	sam 24	
jeu 25		lun 25		lun 25		jeu 25	M M M	dim 25		mer 25	M M M	ven 25	M M M	mar 25		lun 25	A A Tv	mer 25	M M M	sam 25	M M M	lun 25	M M M	jeu 25		dim 25	M M M
mer 26	.04	dim 26		dim 26		mer 26	M M M	ven 26		lun 26	A A Tv	mer 26	M M M	sam 26		mar 26	B B B	jeu 26	M M M	dim 26	M M M	mar 26	M M M	ven 26		lun 26	
jeu 27		mar 27		mar 27		jeu 27	M M M	sam 27		mar 27	B B B	jeu 27	M M M	dim 27		mer 27	M M M	ven 27	M M M	lun 27	A A Tv	mer 27	M M M	sam 27		mar 27	
dim 28		jeu 28		jeu 28		dim 28	M M M	mer 28		mer 28	M M M	ven 28	M M M	lun 28		jeu 28	M M M	dim 28	M M M	mar 28	B B B	jeu 28		dim 28	M M M	mer 28	
lun 29		mer 29		mer 29		lun 29	M M M	dim 29		mer 29	M M M	sam 29		mar 29		ven 29	M M M	dim 29	M M M	mer 29	M M M	ven 29		lun 29	A A Tv	jeu 29	
mar 30		jeu 30		jeu 30		dim 30	M M M	mar 30		ven 30	M M M	dim 30		mer 30		sam 30	M M M	lun 30	M M M	jeu 30	M M M	sam 30		mar 30	B B B	ven 30	
mer 31		ven 31		ven 31		mer 31	M M M	lun 31		lun 31		lun 31		jeu 31	A	mar 31	B B B	mer 31		dim 31		mer 31	M M M	lun 31		jeu 31	

RUN1 suppressed

10% saving requested at national level By French Government

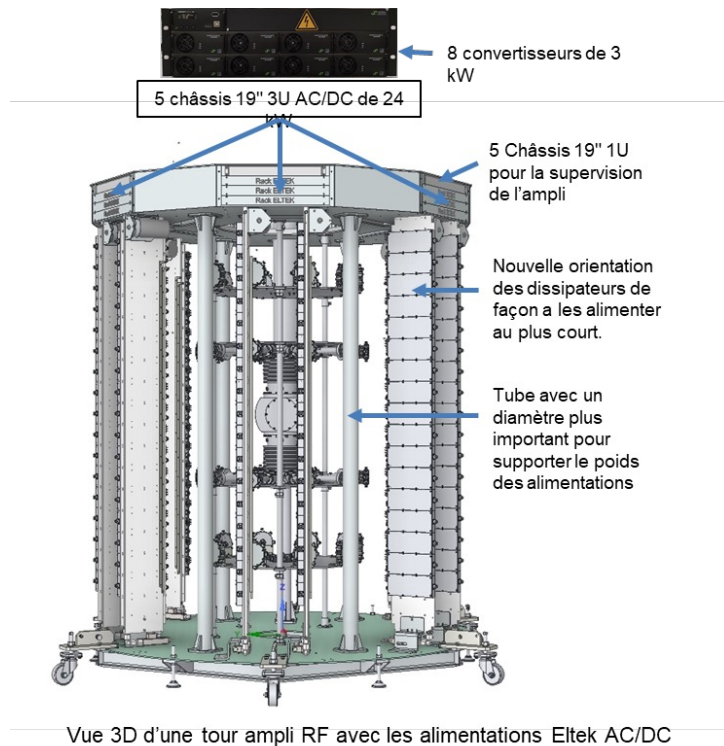
1 bunch , 8 bunch, low-alpha filling patterns converted to high current (450 hybrid or uniform) filling patterns



# Refurbishment of RF amplifier power supplies

## (obsolescence treatment and better energy efficiency)

The power supply upgrade consists of replacing the existing Bruker power supplies and DC/DC converters to address the obsolescence of this equipment and to achieve much higher efficiencies. The **96% efficiency** and the possibility to optimize the RF operating point by controlling the voltage allow a reduction in consumption of **over 20%**. These power supplies, provided with a **30% redundancy**, have a high reliability (MTBF > 350 000 h) and are not very sensitive to "mains" failures.



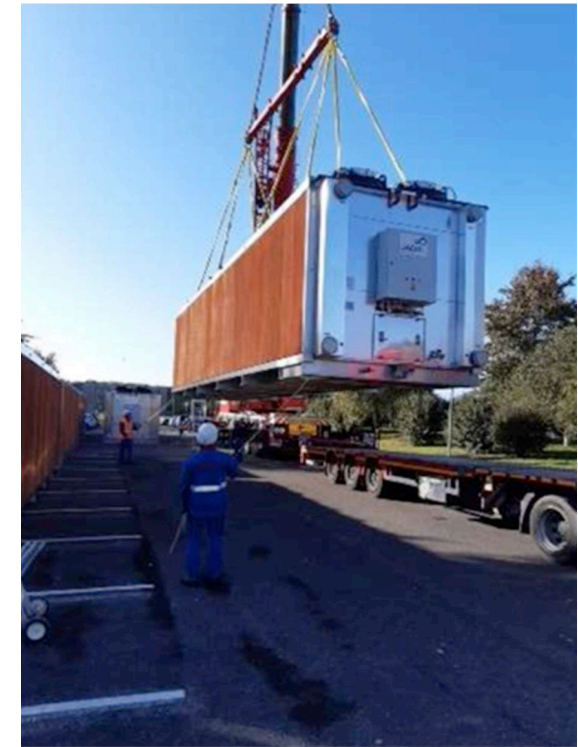
Beam current	450 mA	500 mA
Total RF Power	506 kW	562 kW
Electric Power (today: 4 amplis)	1148 kW	1278 kW
Electric Power (upgrade to 50 V amplis)	1019 kW	1081 kW
Electric Power (upgrade to 44 V amplis)	894 kW	952 kW
Expected consumption reduction	<b>22.1%</b>	<b>25.5%</b>

**Annual reduction in consumption of up to 1.75 GWh**  
**Annual savings of 240 k€**  
**Return on investment of about 4 years**

# New Cooling Station



Total budget: 12.67 M€



Connection to the Synchrotron building expected early 2024.

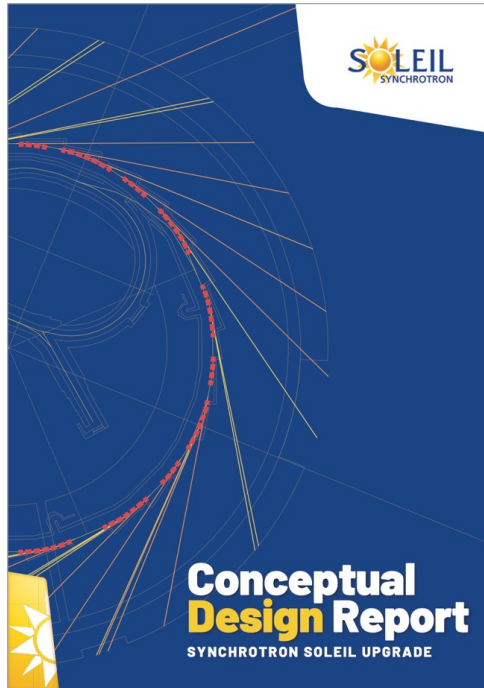
SOLEIL	Electrical Power (kW)	Power Consumption (MWh)	Losses to the air (kW)		Losses to the water (kW)	
			Tunnel	Hall / PS room	Tunnel	Hall / PS room
STORAGE RING POWER SUPPLIES	830	5400	60	75	640	55
TL POWER SUPPLIES	65	420	8	7	45	5
BOOSTER POWER SUPPLIES	130	60				
ID Power SUPPLIES	175	620	10	30	115	20
RF (SR + BOOSTER + CRYO)	1450	8400				
<b>Total</b>	<b>2650</b>	<b>14900</b>				

SOLEIL II (projection oct 2022)	Electrical Power (kW)	Power Consumption (MWh)	Losses to the air (kW)		Losses to the water (kW)	
			Tunnel	Hall / PS room	Tunnel	Hall / PS room
STORAGE RING POWER SUPPLIES	185	1200	40	85	60	0
TL POWER SUPPLIES	65	420	8	7	45	5
BOOSTER POWER SUPPLIES	255	200				
ID Power SUPPLIES	25	80	5	8	10	2
RF (SR + BOOSTER + CRYO)	1000	5800				
<b>Total</b>	<b>1530</b>	<b>7700</b>				

Gain estimation cooling station (T3)                      130 kW                      800 MWh

**Total Gain                      1250 kW                      8000 MWh**

The future use of the new cooling station (T7) will save about 2 GWh.  
 The total gain becomes about: **10 GWh.**



<https://www.synchrotron-soleil.fr/fr/file/13803/download?token=OUzsp46P>

## Upgrade Status



## TOWARDS a 4<sup>th</sup> GENERATION SYNCHROTRON LIGHT SOURCE

- While maintaining the broad spectrum of photons ranging from IR to hard X-rays, the SOLEIL upgrade project aims at **maximizing the intensity of coherent photon flux (highest brilliance and transverse coherence possible)** arriving at the beamlines especially in the soft to tender X-rays photon energy range.

- Three objectives are the key guiding principle for the optimization of the NEW LATTICE.

1. **Electron beam emittances** in both horizontal and vertical planes must be close to the single-electron photon beam emittance in this energy range **(up to 4 keV)**.

- an electron beam emittance of at most **50 pm.rad** in both planes is needed for X-ray energies up to 4 keV.
- obtain a natural horizontal emittance of less than **100 pm.rad** which provides the target of 50 pm.rad in each plane after full coupling.

2. **Insertion device  $\beta$ -functions** close to the matching value.

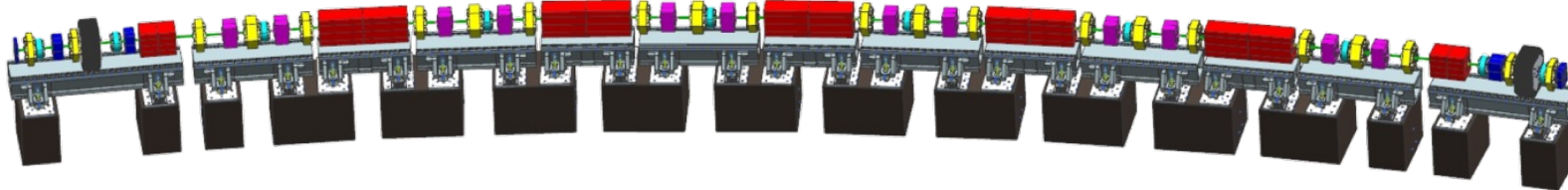
3. **New insertion devices** well optimized (benefit the most from the New Lattice).

*With the highest electron beam current possible (500 mA/uniform fil. pattern )*

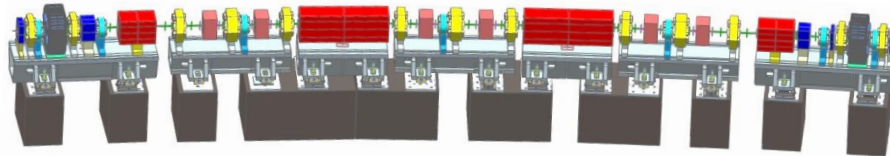


## SOLEIL II Storage Ring Key Features

7BA cell



4BA cell

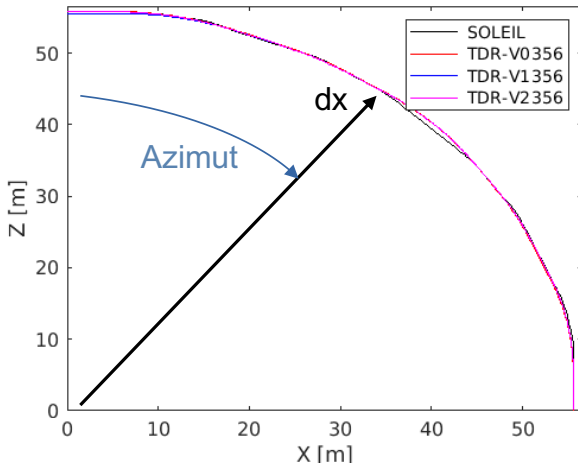


*(Dipole with transverse gradient in red, Reverse Bend in magenta, Quadrupole in blue, Sextupole in yellow and Octupole in cyan)*

1. Non-standard MBA lattice: 12 x 7BA + 8 x 4BA.
2. 85 pm.rad (63 pm.rad with IDs) / 2.75 GeV / 354 m.
3. 20 straight sections ( 4 of ~8 m; 4 of ~4.2 m ; 4 of ~3.6 m and 8 of ~3.0 m).
4. Large photon spectrum (far IR to hard X-rays).
5. NEG coated very small vacuum chamber diameter = 12 mm.
6. Extensive use of permanent magnets (All Dipoles, all RB and all main quadrupoles).
7. Miniaturization.
8. Off-axis injection.
9. High performance Multipole Injection Kicker (MIK).
10. Energy Savings.

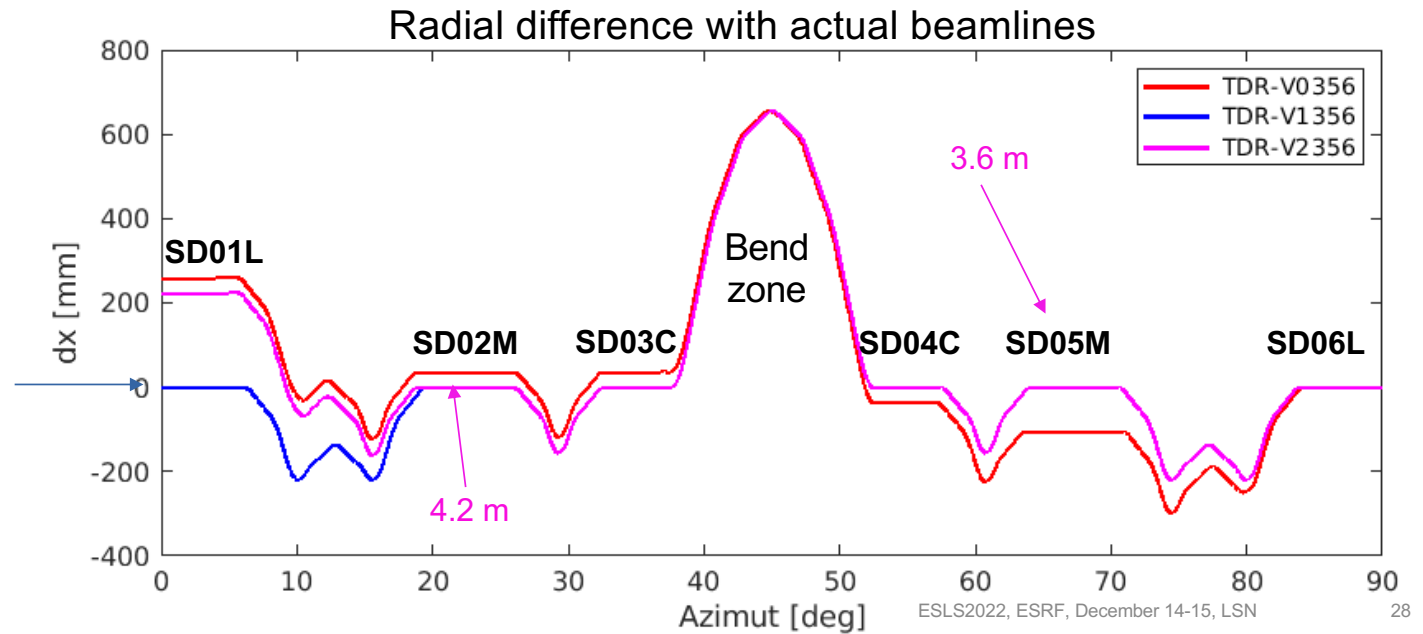
1. Modification of the lattice to perfectly align radially all the ID's Beamlines: **V0356 → V2356**
2. Towards a new version **V2366** (V2356 + better mechanical integration + BBA). **New Baseline lattice.**
3. Reduction of the number of girders from 174 to 86 and the number of plinths from 234 to 172.
4. Launching of the prototype of a "dipole" vacuum chamber to validate all the construction stages including NEG coating in such complex chamber.
5. Launching of the prototype of the sextupole with notch.
6. Launching of the second prototype of the permanent quadrupole.
7. Progress in mechanical integration and light extraction.
8. First prototypes of Insertion Devices & exchange meetings with BL<sup>2</sup> program.
9. Promising new results with the Multipole Injection Kicker (MIK) device.
10. Progress in infrastructure and logistics thoughts.

# Modification of the Lattice to Align Radially all the ID's Beamlines



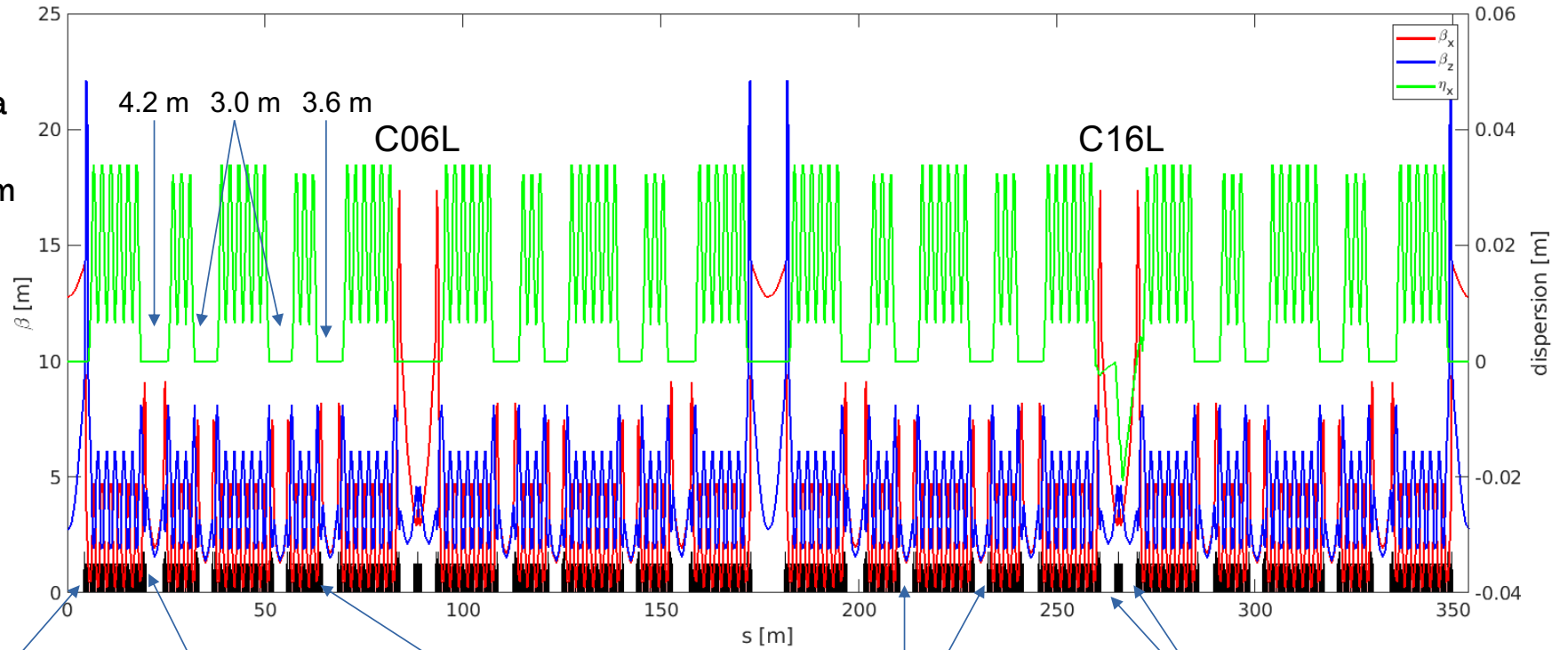
Perfect alignment

- Next step is to split the medium sections in two families : 4 at 3.6 m and 4 lengthened to 4.2 m to be able to accommodate the main RF in SDO2M.
- Only the injection (SD01L) and the opposite (SD11L) presently free for a new beamline are shifted outward by 240 mm.
- **All other ID's beamlines are kept perfectly radially aligned: V1356 → V2356**



## Unchanged main data

Circ. = 353.9618 m  
 Ex = 82.55 pm.rad  
 Jx = 1.85  
 MCF =  $1.065 \cdot 10^{-4}$   
 UO = 454 keV/tr  
 Tune = 54.2 18.3



*Injection section*

$L = 8m$   
 $\beta_x \sim 12.7m$

*Medium – long*

$L = 4.2m$   
 $\beta \sim 1.7m$

*Medium – short*

$L = 3.6m$   
 $\beta \sim 1.6m$

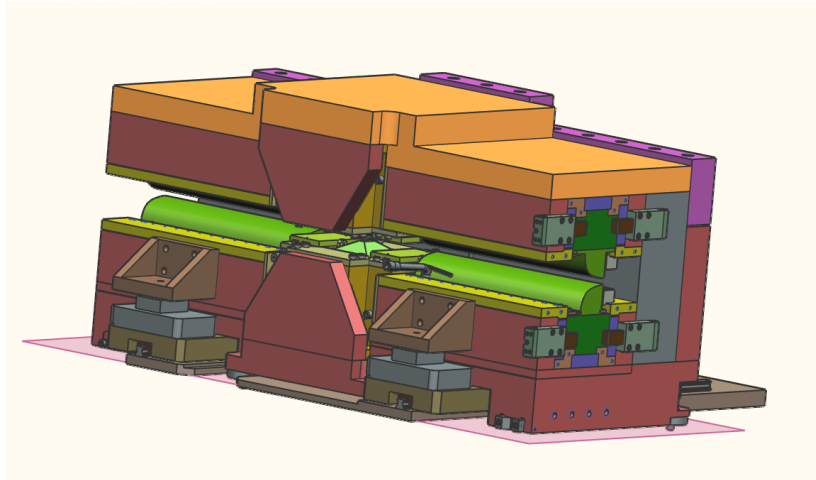
*Short*

$L = 3.0m$   
 $\beta \sim 1.3m$

*Double low beta*

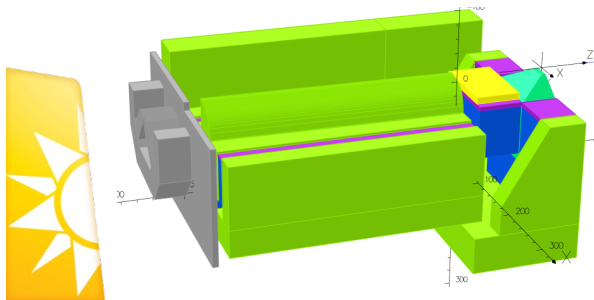
$L = 3.5m$   
 $\beta_z \sim 2.1m$

# A Selection of Prototypes

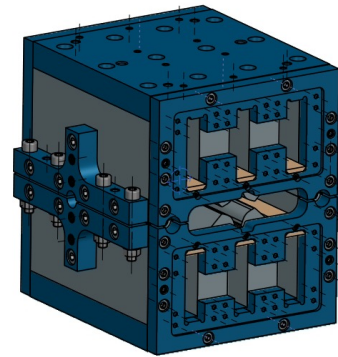


PM Long Combined Dipole (3T)  
3 pieces: Sm<sub>2</sub>Co<sub>17</sub> (PM) + Low Carbon Steel (LCS)  
Gap 22 mm

Cross-talk between magnets under study

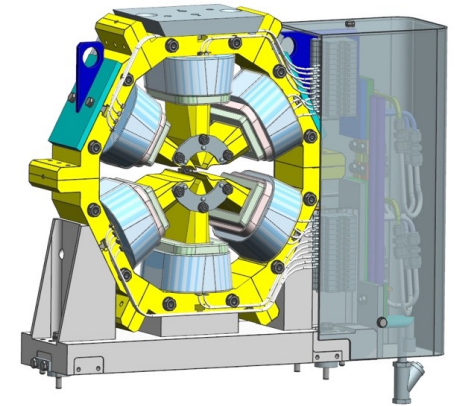


100 T.m-1 Aperture  $\varnothing$  21 mm



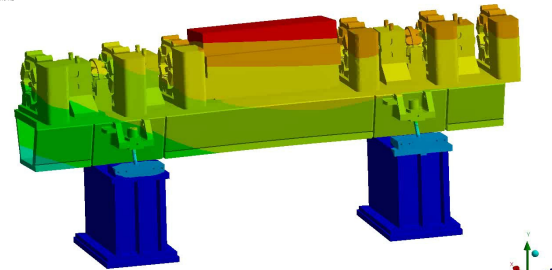
Second prototype  
Permanent Magnet Quadrupoles

8200 T.m-2 Aperture  $\varnothing$  XX mm



3D view of the sextupole  
prototype with notch  
Expected delivery but April  
2023

© Procter 1 dipole analysis module  
Total Deformation: Max: 1.46116e  
Spec: Total deformation  
Imp: mag 001316  
Unit: mm



Girder Prototype expected in 2023

# MIK: Prototype V1 testing: electrical testing (in-air)

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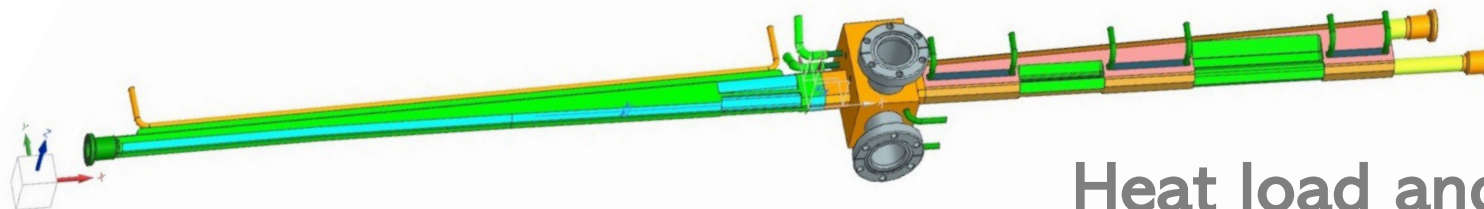
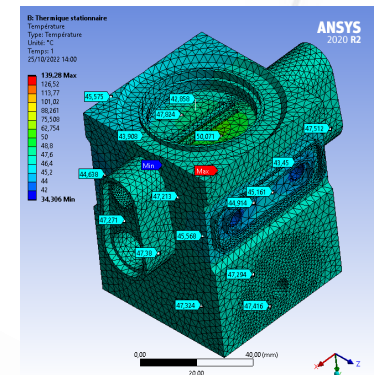
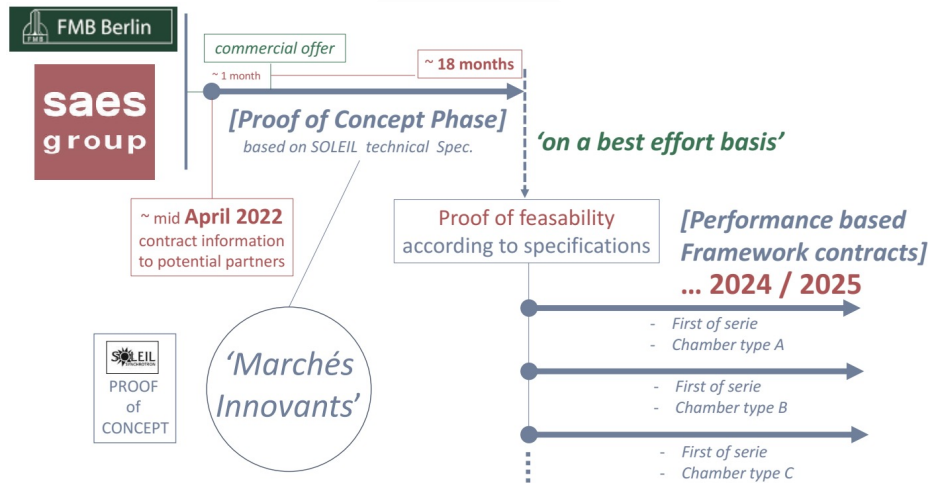
- **Parts for prototype V1 delivered on time (July 2022).**
  - Assembled a first version with Kapton insulated copper wire (UHV compatible).
  - Second version (*same MACOR parts*) will be assembled with bare copper wire.
- **Dedicated pulser assembled and commissioned.**
  - Traditional short coaxial transmission (10 m) capacitive resonant discharge topology.
    - *Worst* voltage per amp ratio on the magnet ( $\sim 3$  kV / kA).
    - Better topologies are studied.
  - Tested up to 10 kV – 3 kA – 2.2  $\mu$ s on dummy load.
- **Prototype V1 electrical tests**
  - Pulsed at 6.5 kV – 2 kA without liners: no issue with arcing between conductors.
  - Inductance of 1.095  $\mu$ H & resistance of 116 m $\Omega$ , as per calculated in FEA simulations.
    - Value used for pulser design.
- **Future tests in air then in vacuum (Q4 – 2022).**
  - UHV electrical connections & magnet.
  - Uncoated liners with simulated grounding.
  - In-air additional connections as per complete magnet model.



## Update info for Proof-of-concept phase for high stake chambers

to evaluate the 'showstoppers' of the *Mechanical and NEG coating deposition issues* a "Proof of concept" phase was initiated with FMB Berlin and SAES Group for a generic Dipole chamber

Based on that objective, Upgrade Chambers procurement will be done on "Performance based Framework contracts"

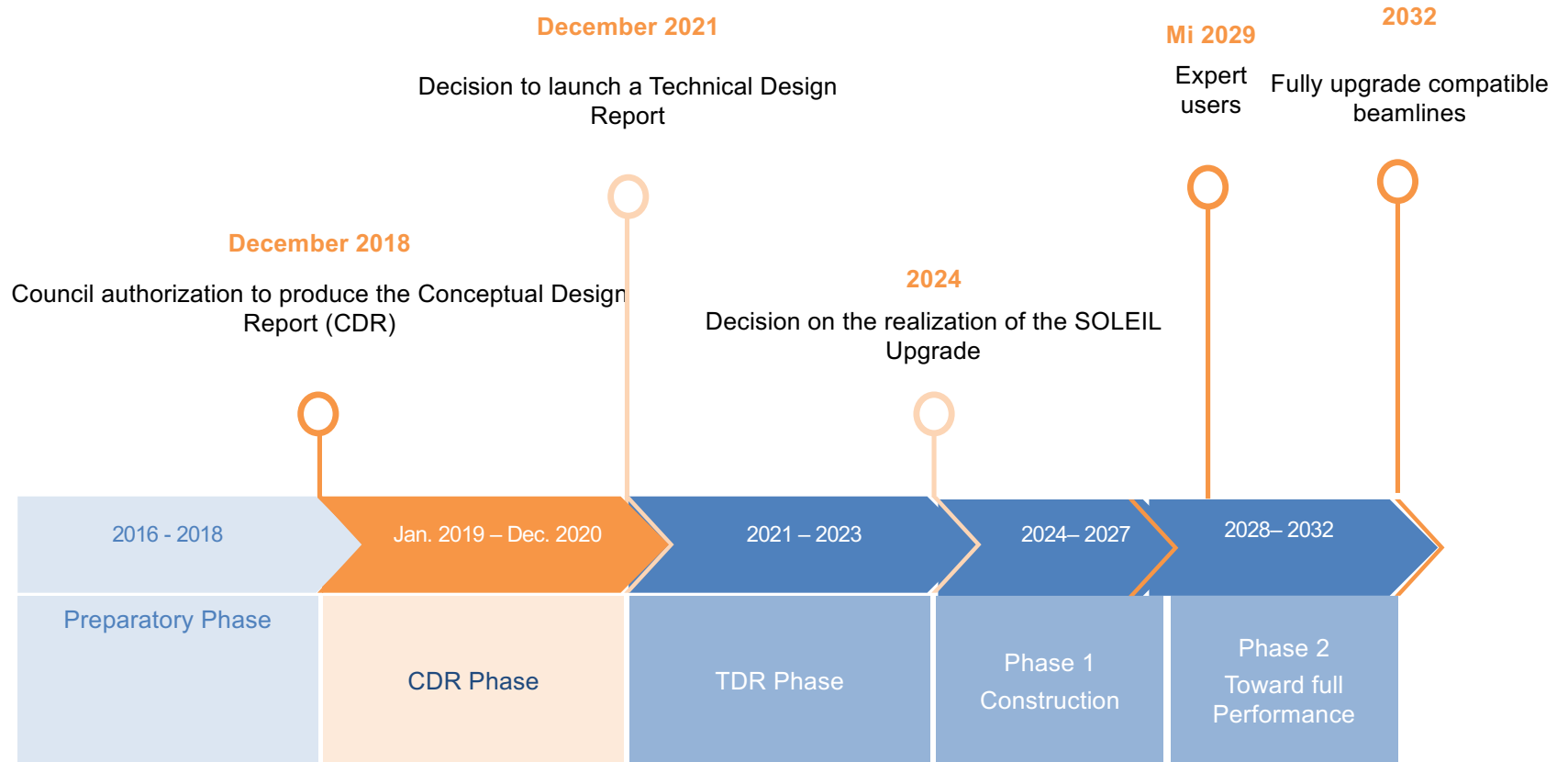


## Heat load and power handling





# Present SOLEIL II Timeline



# Conclusions



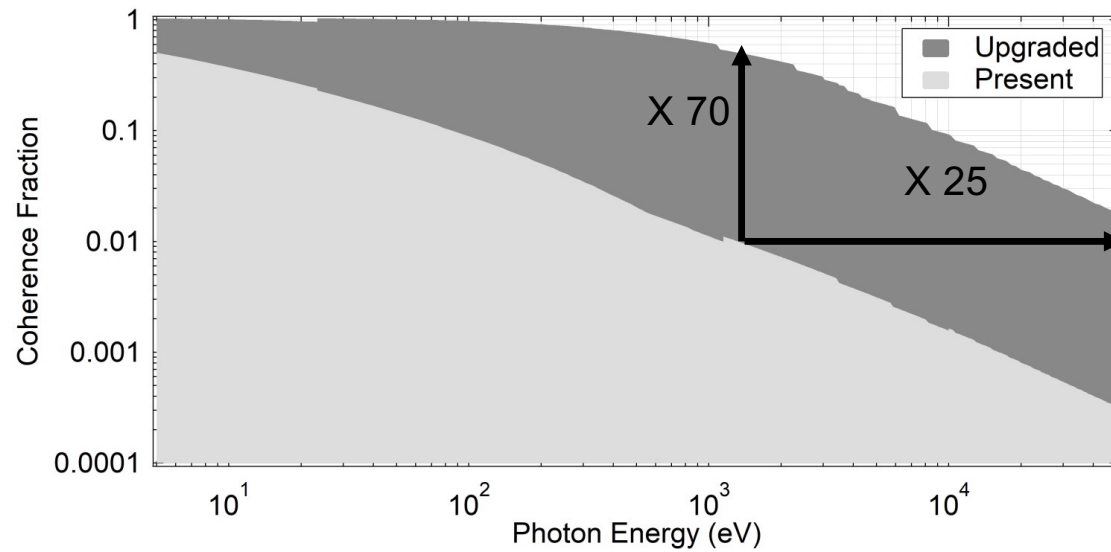
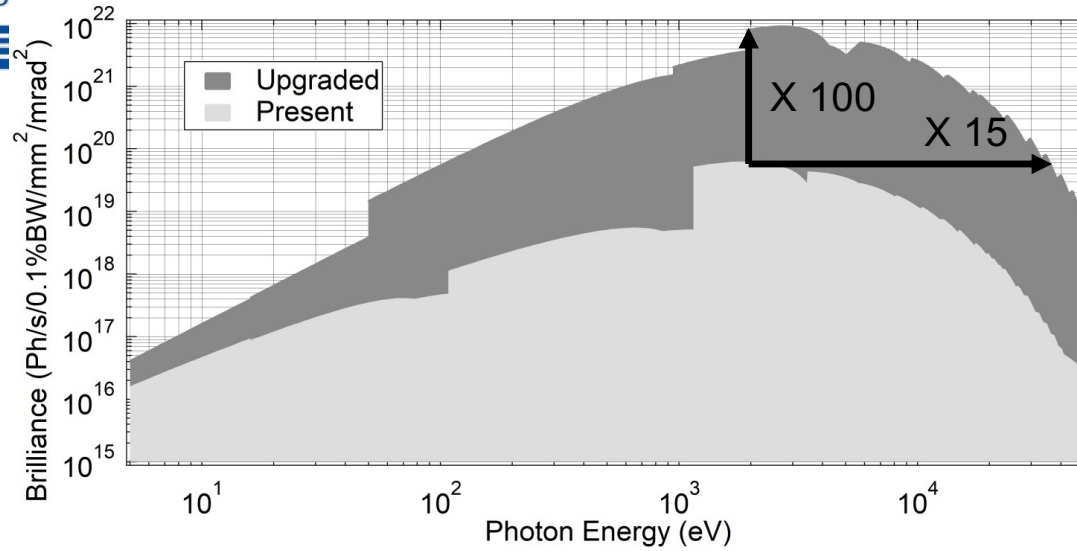
- **SOLEIL:**
  - Another year with high performance
  - Test bed for testing new technologies for the upgrade
  - LINAC upgrade (spare buncher under construction, increase of energy under consideration)
  
- **SOLEIL II**
  - Storage ring
    - Mechanical integration in progress
    - Heavy Prototype phase to remove all possible technical bottle necks
    - Ray tracing and Machine interlock
    - Selection of the main photon sources
    - Collimation studies
    - Logistics and Human resources
    - Reinforced Interaction with the Experimental Division
  - New Booster (150 MeV to 2.75 GeV, 3 Hz)
    - Mechanical integration
    - Modification of the transfer lines



# Appendix

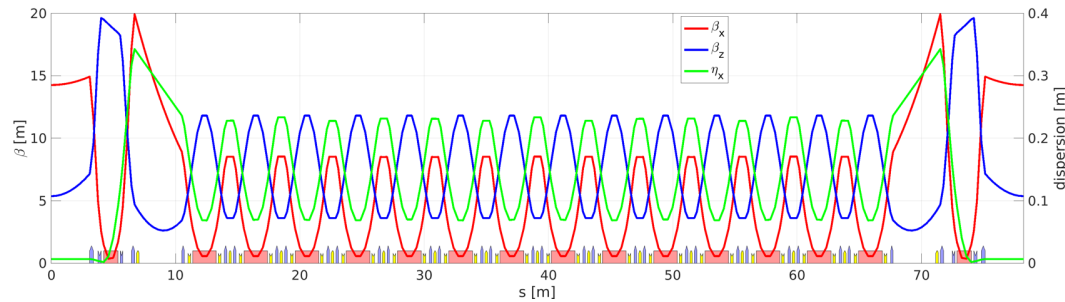


# PHOTON BRILLIANCE AND TRANSVERSE COHERENCE



# BOOSTER UPGRADE PROGRESS

- Two top-up injection schemes into the storage ring upgrade still being studied: betatron off-axis injection and on-axis chromatic injection, using the MIK device. Both need a drastic reduction of booster emittances in transverse and longitudinal planes at the extraction energy.



- 16BA HOA type lattice:** 14 unit cells including combined function dipole (D+TG), two matching cells, a 6.2 m long straight section and two 3.44 m short straight sections.
- Reuse of the 2 RF systems** at the same place in short straights (copper units each comprising 5 cells @ 352 MHz, LEP type).
- Reuse of the injection system, necessary renewal of the extraction system.** Thick septum of booster extraction foreseen in permanent magnet and mutualized with the SR injection one, to minimize the angular/position jitter of the injected beam into storage ring.

Parameter	Unit	Target	Present booster	New designed booster
<b>Energy range</b>	<b>GeV</b>	<b>0.15 – 2.75</b>	<b>0.1 – 2.75</b>	<b>0.15 – 2.75</b>
Circumference	m	-	156.6	156.46
<b>Natural emittance</b>	<b>nm.rad</b>	<b>&lt; 10</b>	<b>140</b>	<b>5.2</b>
<b>RMS bunch length</b>	<b>ps</b>	<b>&lt; 25</b>	<b>50 @ 3 MV</b>	<b>25 @ 3 MV</b>
Nat. chromaticities	-		[-7.3,-5.8]	[-27, -12]
M.C. F.	-		$2.8 \cdot 10^{-2}$	$3.3 \cdot 10^{-3}$
Energy loss / turn	keV		409	554
Energy spread	-		$0.66 \cdot 10^{-3}$	$0.93 \cdot 10^{-3}$
Max. RF voltage	MV		3.6	3.6

