SOLEIL: Status & Upgrade

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on behalf of the Accelerators and

Engineering Division

Layout

- SOLEIL 3GLS facility
  - SOLEIL operational status
  - Selected highlights
  - CoViD-19 challenges on organization and operation
- SOLEIL upgrade Status towards 4GLS
  - CDR phase
  - Challenges
  - Tentative schedule

Lattice

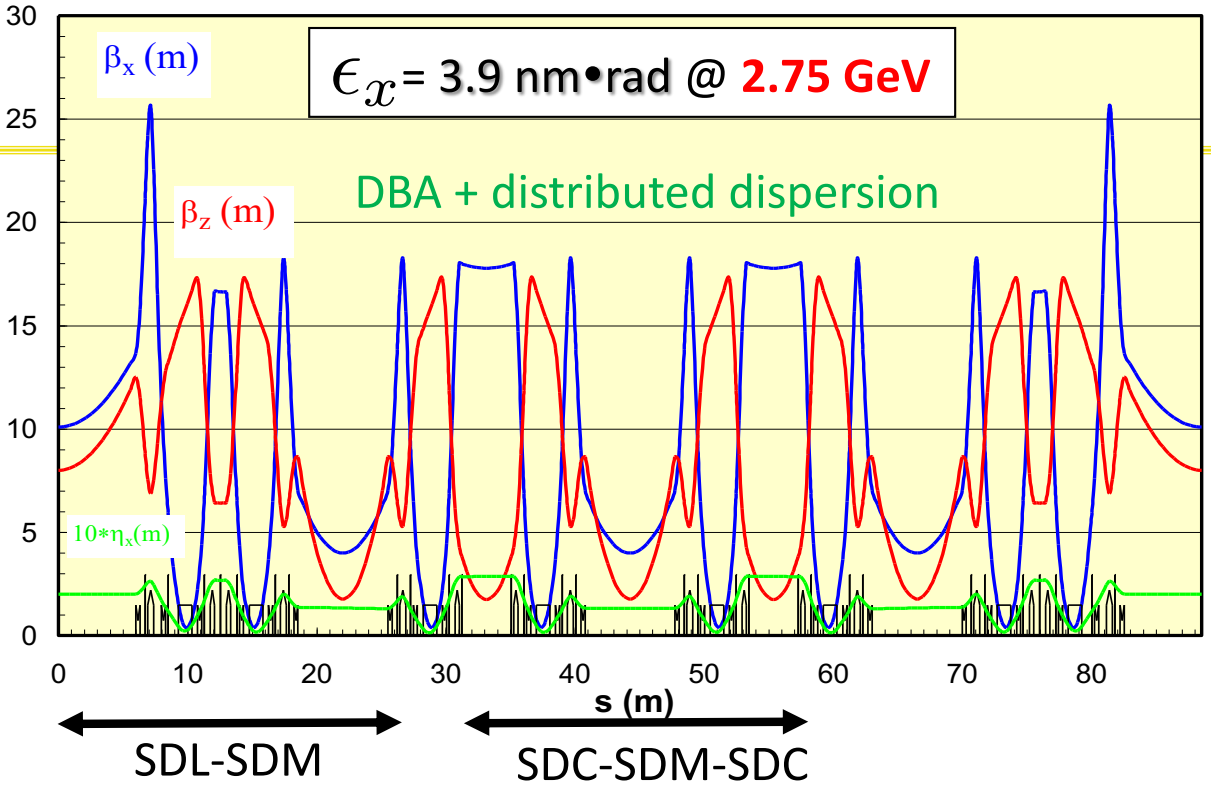
Location: France

Circumference: **354 m**

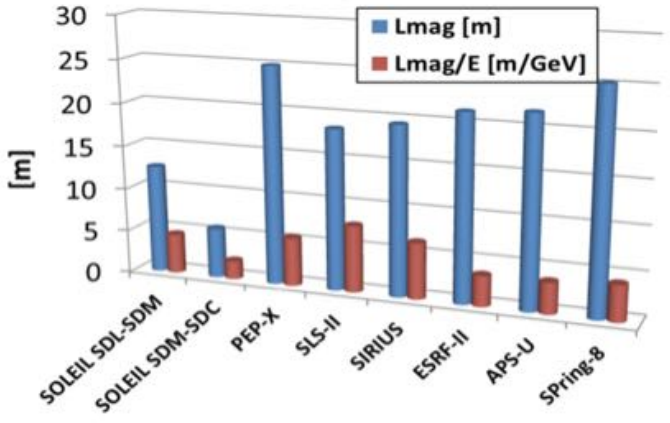
24 straight sections

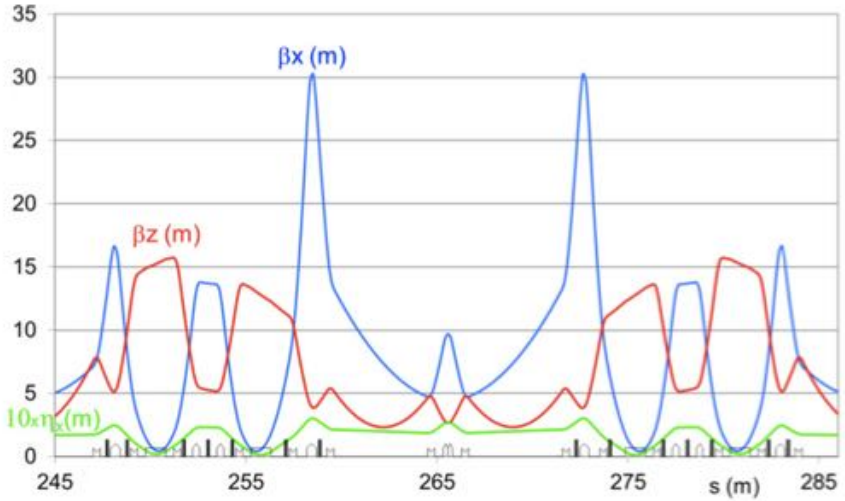
(variable length)

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



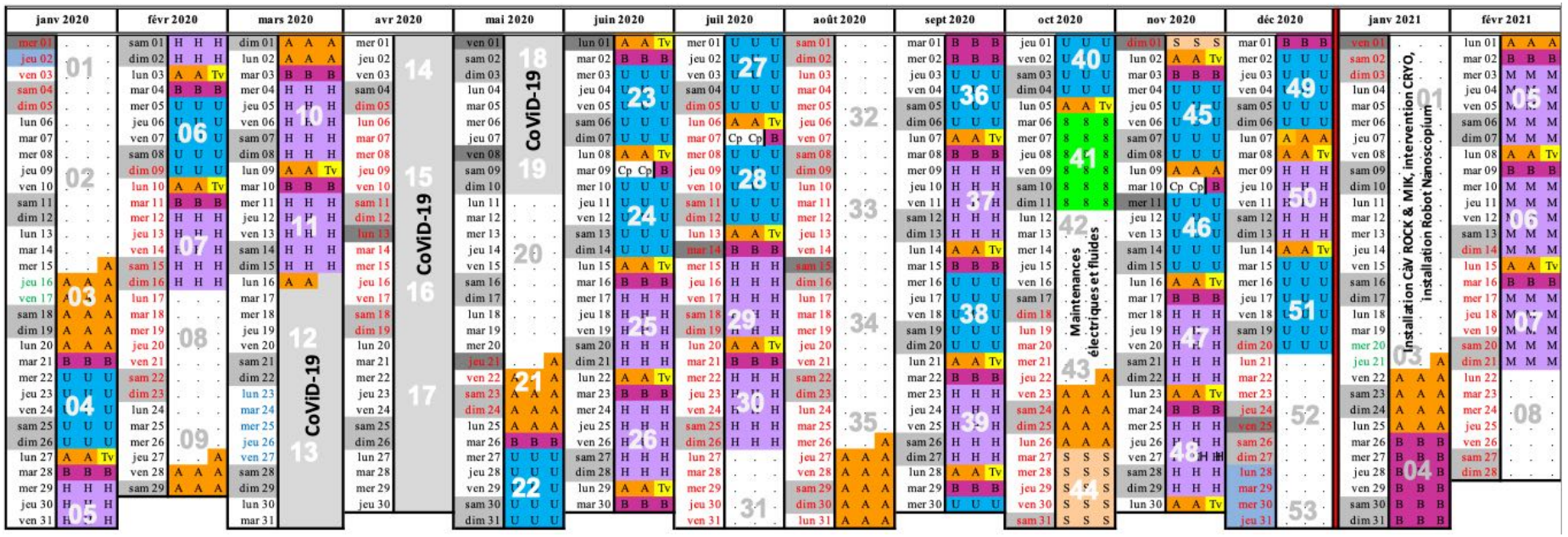
Very compact magnetic structure





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

Beam Time Schedule in 2020

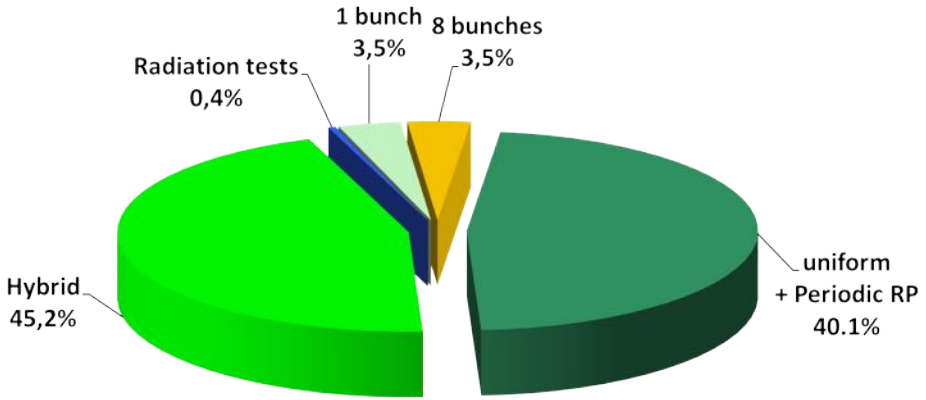


CoViD-19 lock-down: 7 weeks

U		Uniform
H		Hybrid
8		8 bunches
S		1 bunch
L		Low -Alpha
B		Beamlines
Cp		Periodic radiation safety checks
Tv		Radation safety validation
A		accelerators
.		Shutdow n

29 beamlines

Beamline and radiation safety test (4096 hours)
Beam time according to filling patterns

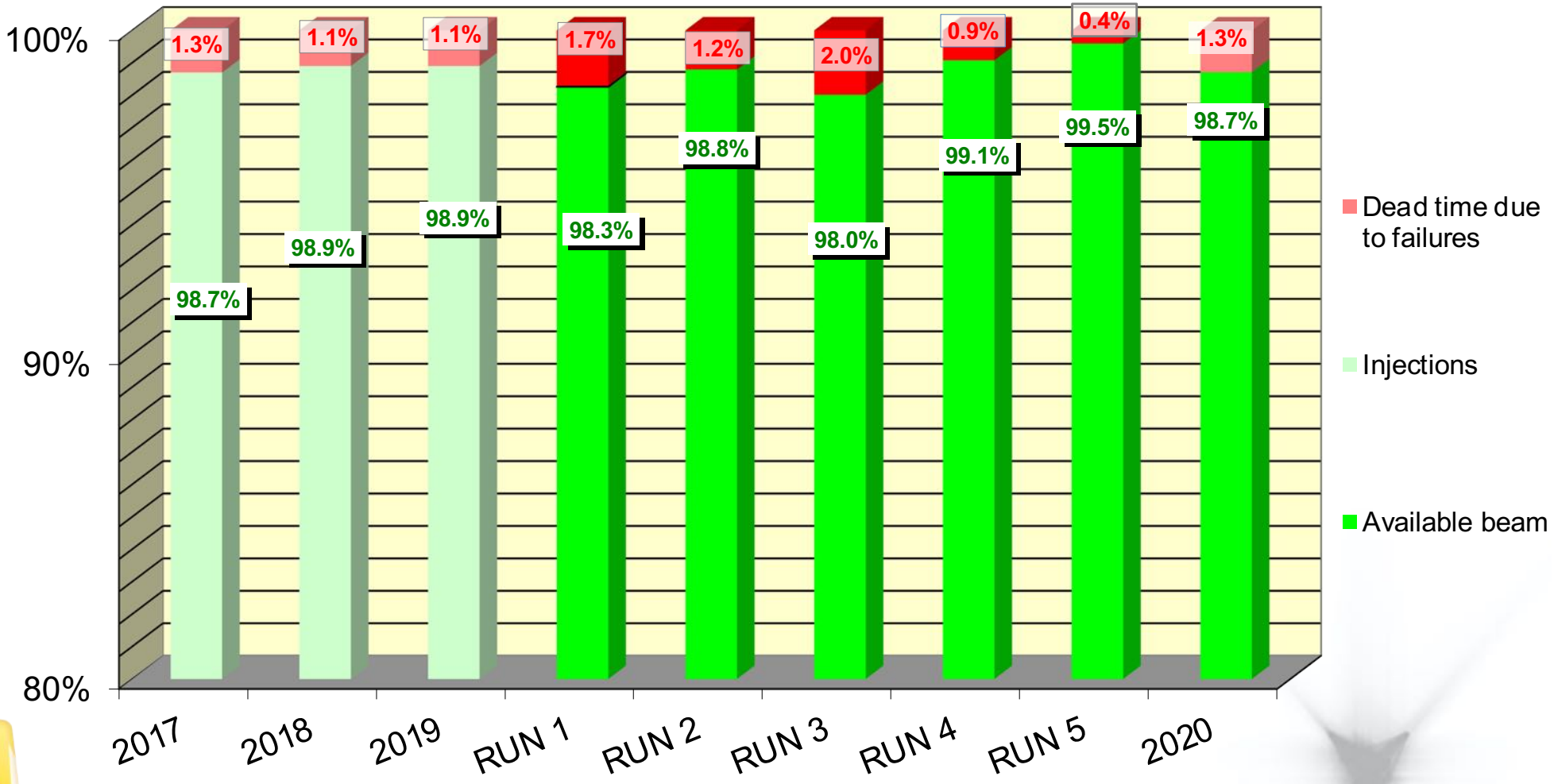


Beam availability: **98.7%**

MTBF: **100h**

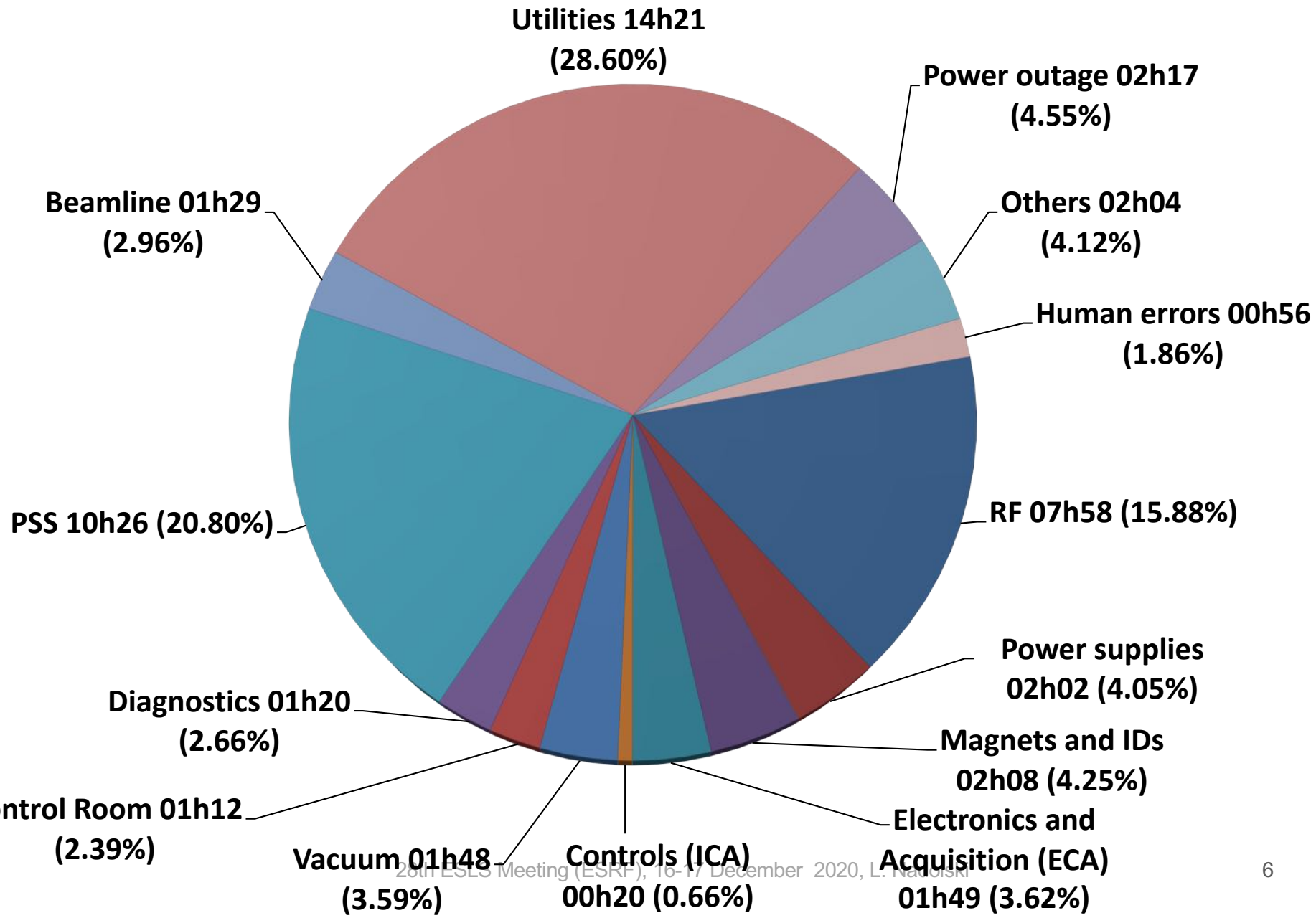
Efficiency during beamlines and radiation safety sessions in 2020

3825 hours of beamtime delivered
represent a beam availability of 98.7 %
until the 6th week of RUN 5

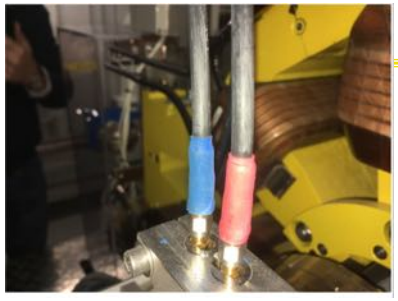


Origin of the 50 hours without beam in 2020

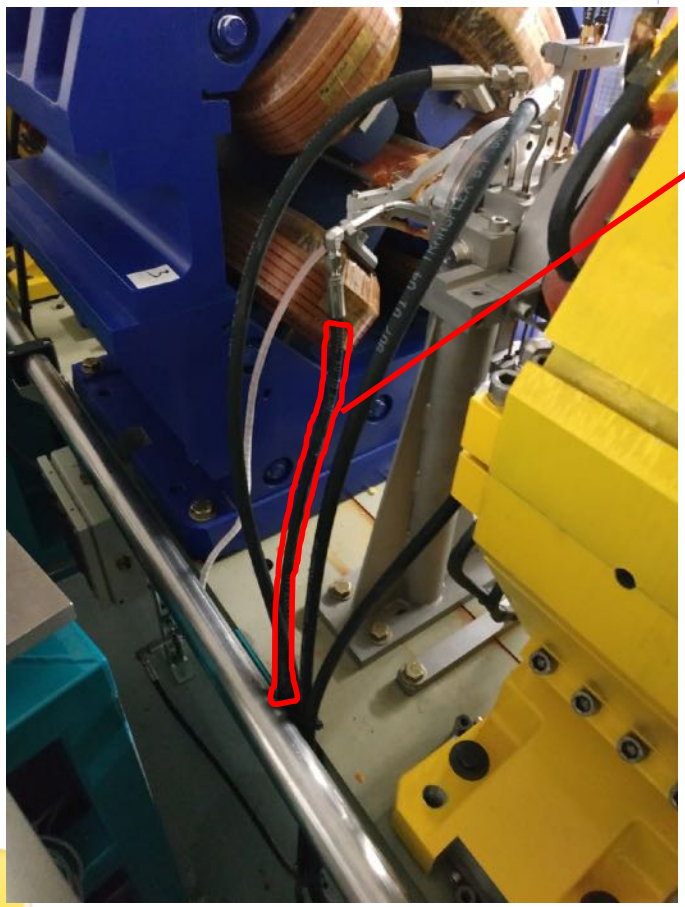
(until the 6th week of RUN 5)

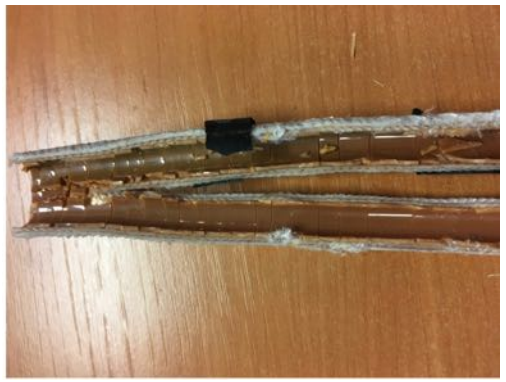


Preventive and corrective maintenance

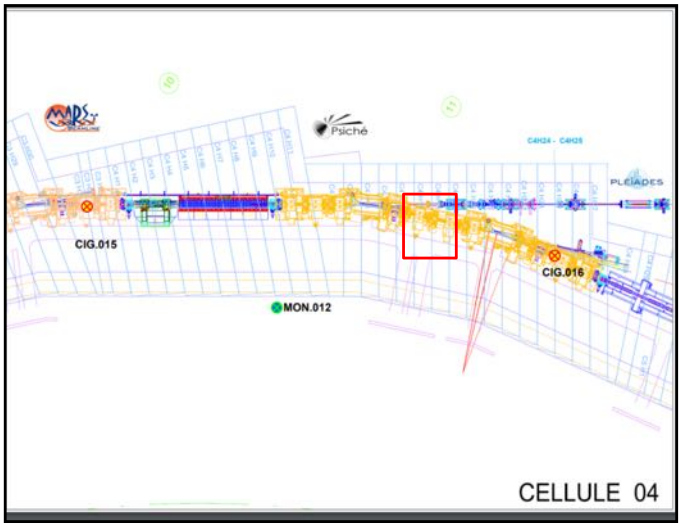


Radiation induced aging of many water cooling hoses





Exuding water along the hose (1 drop/sec)



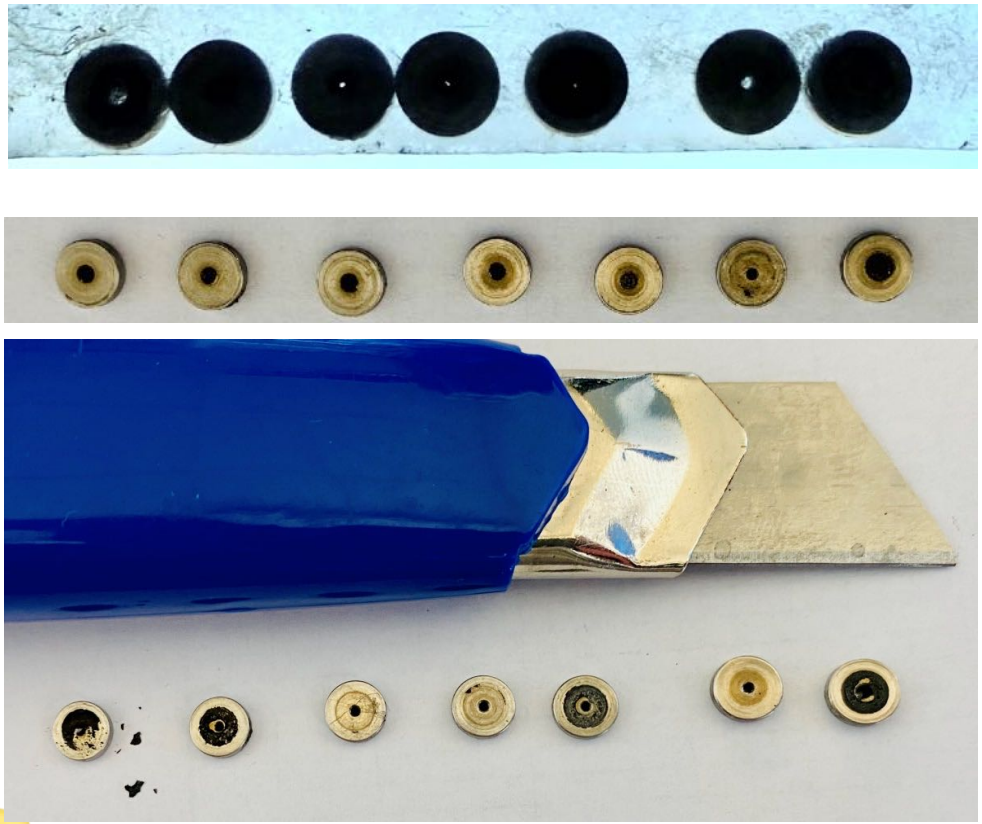
All hoses downstream to dipoles and located on the external side of the tunnel are to be replaced

An aging facility: increase of flowmeter faults

Clogging of waterflow reducers leading to an increase of flowmeter faults

Even with a large cleaning campaign 2 years ago for all the BPMs

ELETTA flowmeter: retuning regularly by reaching the lower limit (radiation damage of the membrane ?, calibration), need of a dedicated maintenance or partial replacement after more than 15 years of operation



Eletta Flowmeter

CuO deposit (black) blocking the diaphragms of the 21°C water cooling circuit

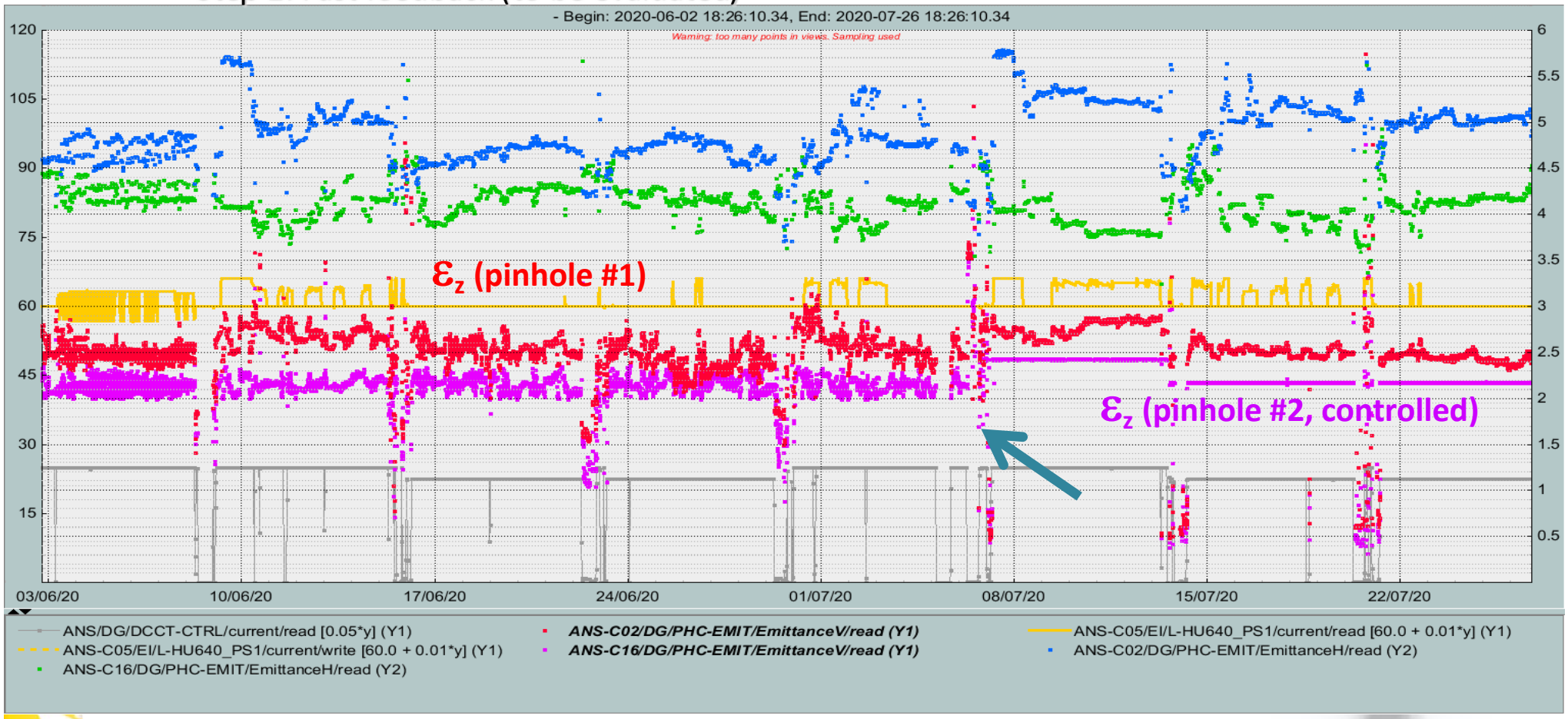
Selected Highlights

Major update since ESLS'19 https://indico.cells.es/event/224/contributions/889/attachments/724/1099/ESLS2019_SOLEIL_1.pdf

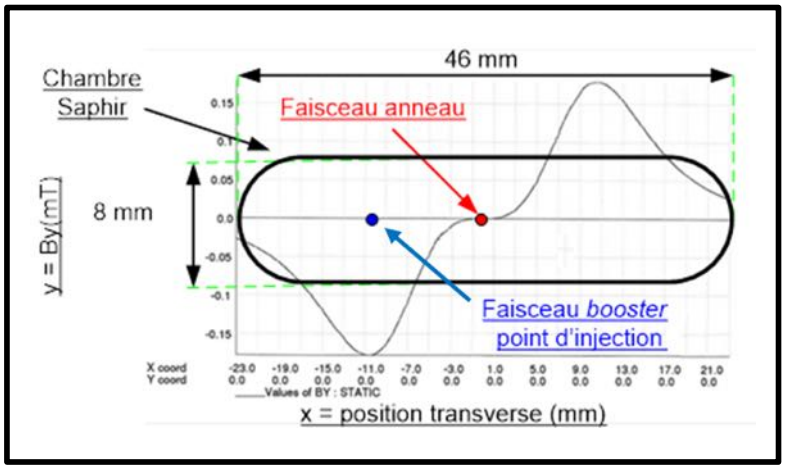
- New coupling feedback with white noise
- Multipole Injection Kicker project
- Superbend project
- Photo Desorption "BeamLine"
- New set of beam loss monitors

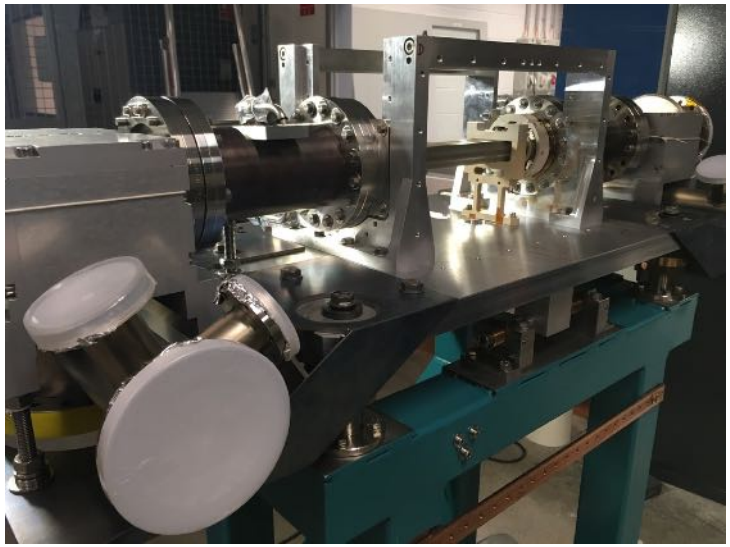
New Beam size Feedback

- **Use of noise generator at minimum of coupling (TFB processor) instead of exciting a vertical dispersion wave**
  - Step 1: Slow feedback 2 Hz (in operation)
  - Step 2: Fast feedback (to be evaluated)

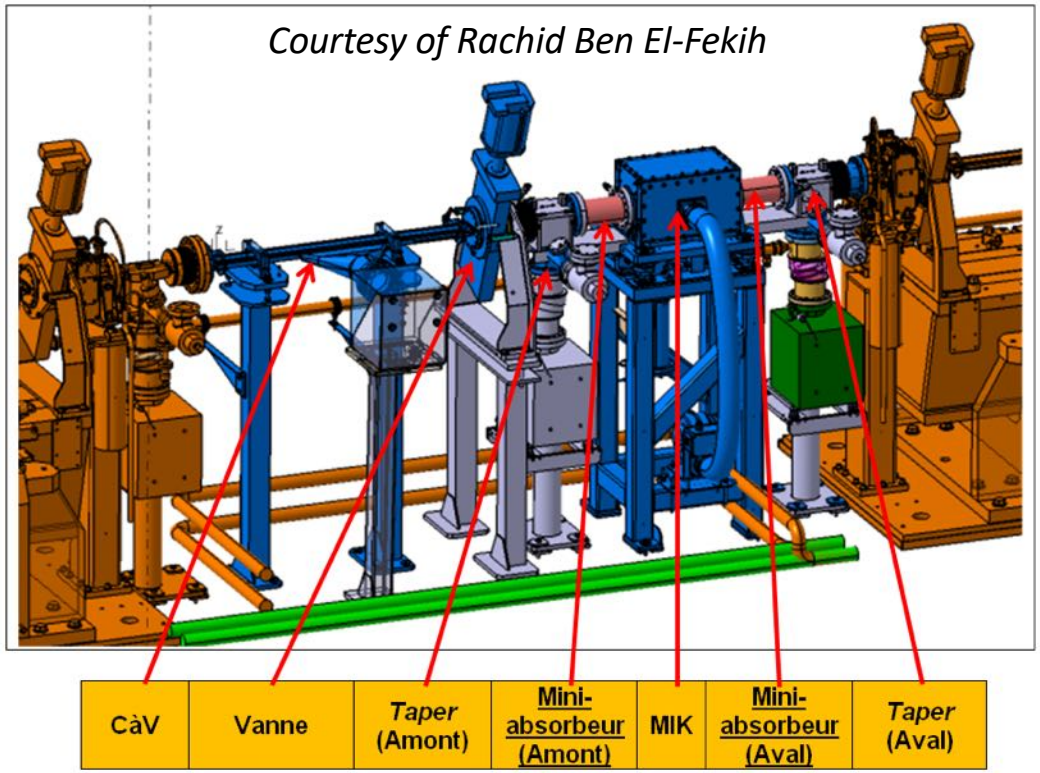


Installation of the MIK @ SOLEIL





Installation of the MIK in an available Short Straight Section



Same geometry as the one installed at MAX-IV
https://doi.org/10.1016/j.nima.2020.164739

Update (since ESLS 2019)

- Ti coating of Sapphire Chamber (ESRF)
- In-house magnetic measurements
- Test of new types of absorbers

Installation: January 2021 (preparing the upgrade)

- Test the MIK concept on SOLEIL : efficiency, orbit perturbation.
- Test of injection schemes in the framework of the upgrade studies
- On axis Injection with Transverse kick combined with longitudinal kick with the RF

Dedicated Photo Desorption Beamline for the upgrade

Balance between Photon Stimulated Desorption yield η
& the NEG Pumping speed / saturation-capacity
→ For 10 mm diameter chamber ←

What would be the dynamic pressure and its evolution with the photon DOSE

2 TEST BENCHES @SOLEIL

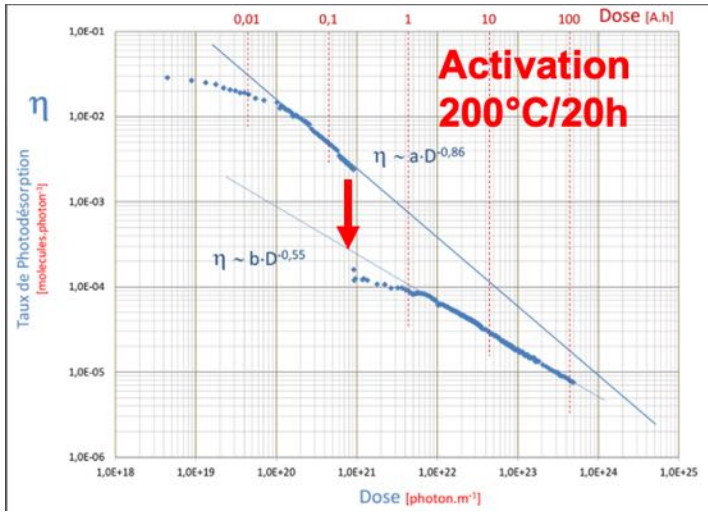
On the ring

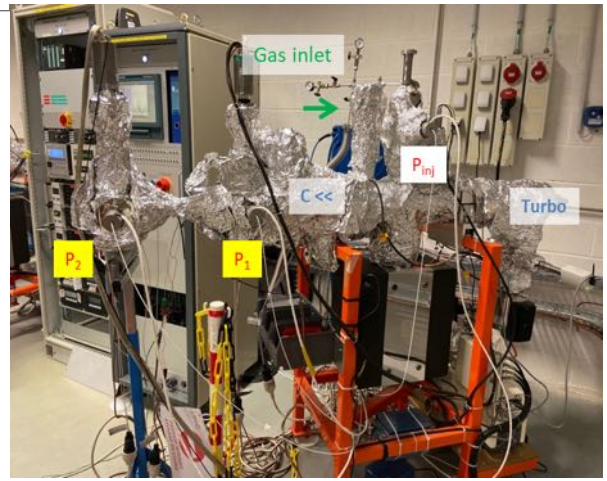
PSD η / ***Dose*** of photons
- Activation NEG with SR ?
- Pumping CH4?

In the LAB

- **Intrinsic pumping speed of the NEG S^{NEG}**
- **Capacity/saturation**

with Injection gas pure/µleak
H2, CO, CO2, CH4.....





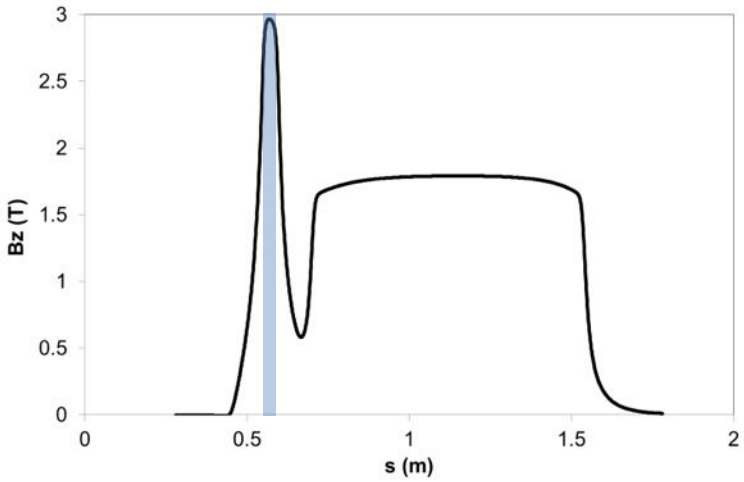
First chamber tested (63 mm diameter)
Successfully during fall 2020

Characterization bench

3T Superbend Project (ROCK BL)

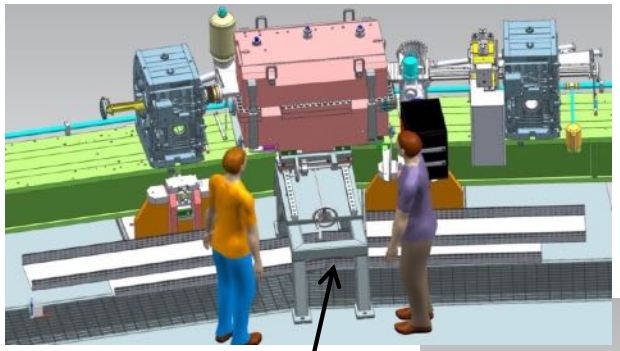
Permanent magnet dipole(NdFeB)

Length 1.260 m



Gap **16.1 mm**
B = **2.84 T**

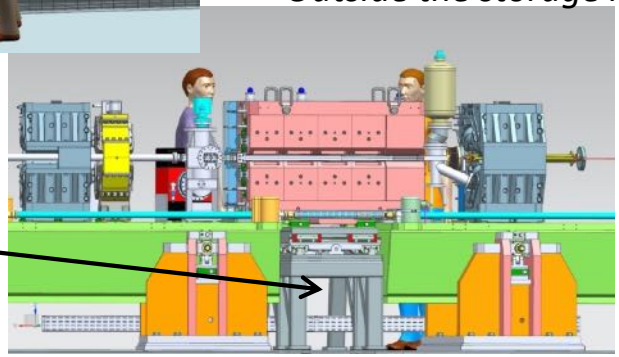
Gap **23 mm**
B = **1.81 T**



Inside storage ring

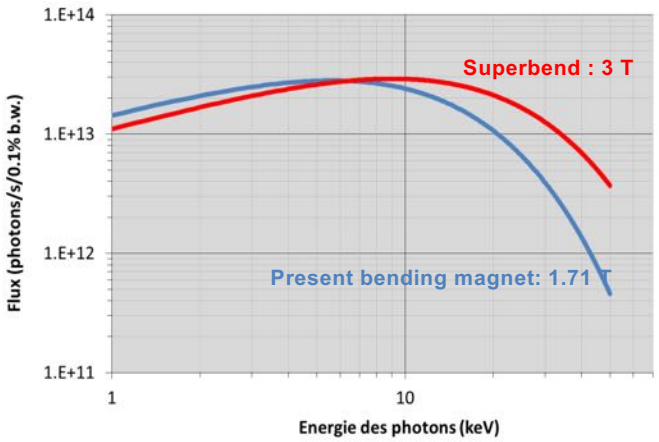
A C-shape yoke which allows the removal of the magnet for bake out

Outside the storage ring



Magnet remove device for bake out

Installation: January 2021

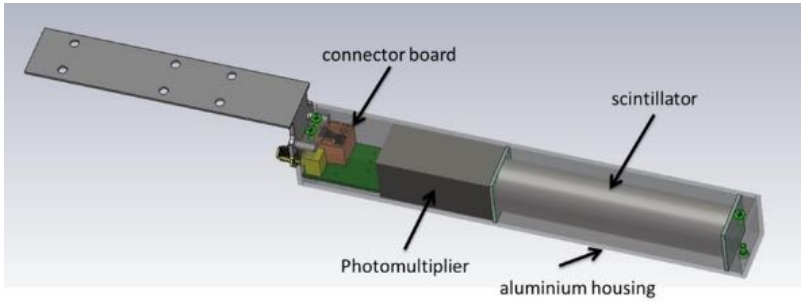


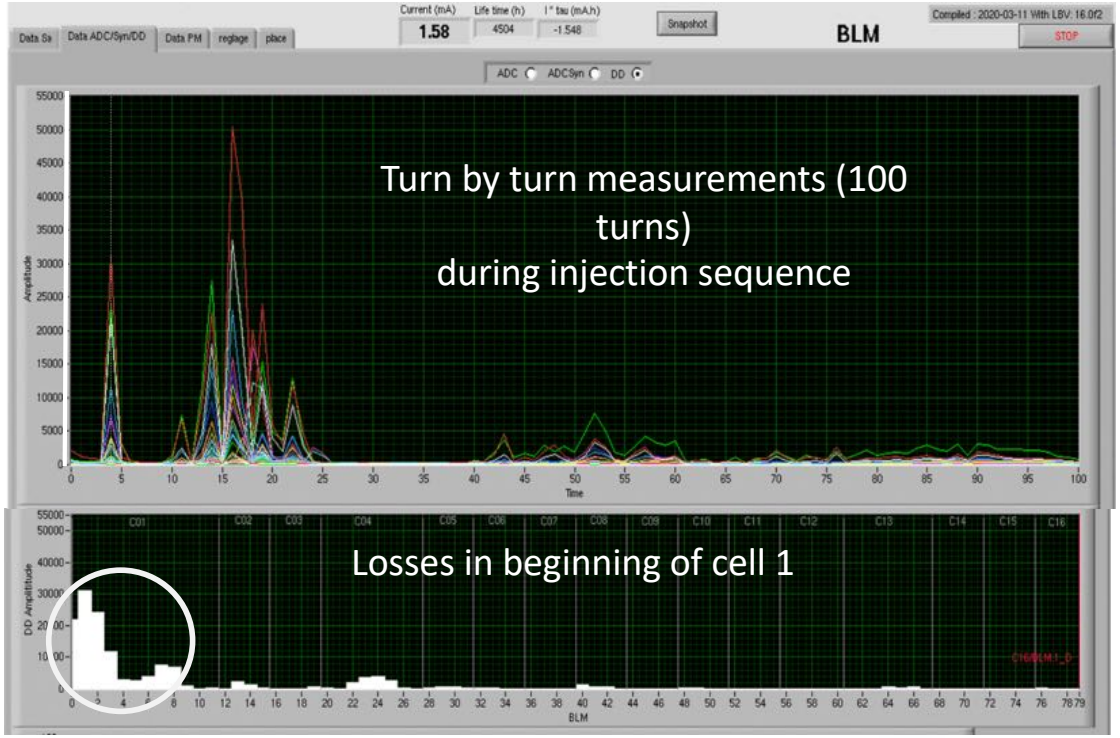
Calculation at 8700 mm from the source point for an opening of 13 x 2.4 mm².

Installation in August 2021

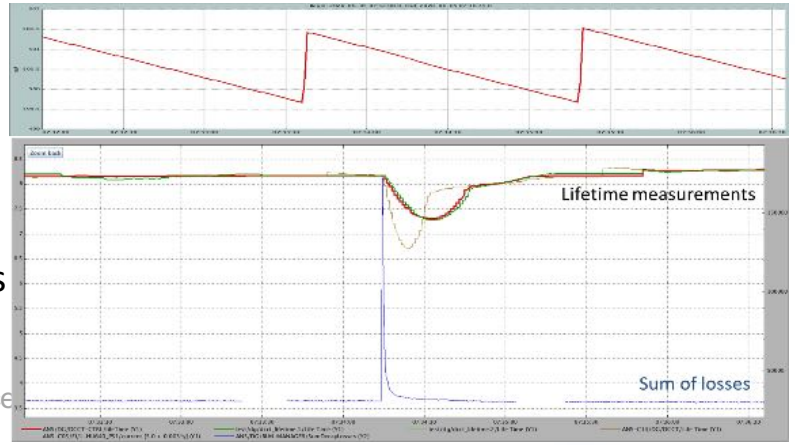
Courtesy of Pascale Brunelle

80 New Beam Loss Monitors across the storage ring





- **Average data (13 Hz)**
- **Turn by turn (injection)**
- **Fast measurement**



Upgrade: radiation safety

Measurements vs FLUKA simulations for qualifying the shielding walls

SOLEIL garde le contact infos confinées

CoViD-19 impact

- Coordination and organization
  - Crisis Meeting once a week
  - Heavy work (safety, communication, crisis cell) to produce adequate documentation, safety and training sheet, answering questions...
    - **On-line training for all the staff & making the working environment safe**
    - **Psychosocial risk (PSR),** etc.
  - Maintaining the link with the employees: a newsletter « **Informations Confinées** ».
  - **Facility Shutdown (national lock-down) for 7 weeks** (16 March – 11 May)
  - **11 May : going back progressively to work (4-5 main phases)**
    - **Phase 0** (May 11th - June 22nd): operation with highest priority.
    - **Phase I** (June 22nd – July 6th): ~50 % of technical staff on site. Everybody has to come back at least once. Authorization still necessary to enter the site.
    - **Phase II** (June 22nd - July 6th): staff at least present 2 days a week. Number of people in a room only limited by the 4m² rule, or mask.
    - **Phase III** (from August 31st): Max of 2 days home office per week.
    - **Phase IV** (from October 30th) : 2nd lock down. Almost normal operation. Teleworking is the rule when possible. A few cancellations (Users).
  - **Supporting the economic activity**
    - From June 2nd, service provider back on site
    - Corporate restaurant, guest House, etc.
- Remote Access
  - Allowing a maximum number of people to telework
    - Generalization of remote Access to the Accelerators
  - Rescaling of IT architectures and purchasing VPN, Microsoft TEAMS, etc. licenses.
  - Adaptation of workplaces
  - Creation of a task force for remote access of the beamlines (29 BL working, 5 CoViD BLs, 1/3 Mail-In, 1/3 partial or total remote access)


CoViD-19
Consignes pour la reprise d'activité sur le site du Synchrotron SOLEIL

Salariés de SOLEIL, restez informés !

Consultez régulièrement le site intranet.
Consultez régulièrement votre boite mail. Les messages de la cellule de crise sont envoyés depuis l'adresse coronavirus@synchrotron-soleil.fr
Vous devez utiliser cette adresse pour poser vos questions concernant la situation liée au CoViD19

Vous entrez sur le site du synchrotron SOLEIL

Suivez les consignes de ce document pour préserver votre santé et celle des autres
Ces consignes pourront évoluer en fonction des instructions gouvernementales

Lors de votre premier passage, pour entrer sur le site vous devez :

- Suivre la formation en ligne et réussir le questionnaire sur les mesures de sécurité spéciales CoVid-19 (en cours d'élaboration)
- Retirer votre kit (personnel SOLEIL seulement) à l'accueil, en respectant le sens de circulation et les règles de distanciation (au moins 1m)
- Signer une attestation indiquant que vous avez pris connaissance et compris les consignes données dans cette plaquette

SOLEIL SYNCHROTRON

Safer Control Room
Limited access
+
Second Control Room

SOLEIL Upgrade News and Status

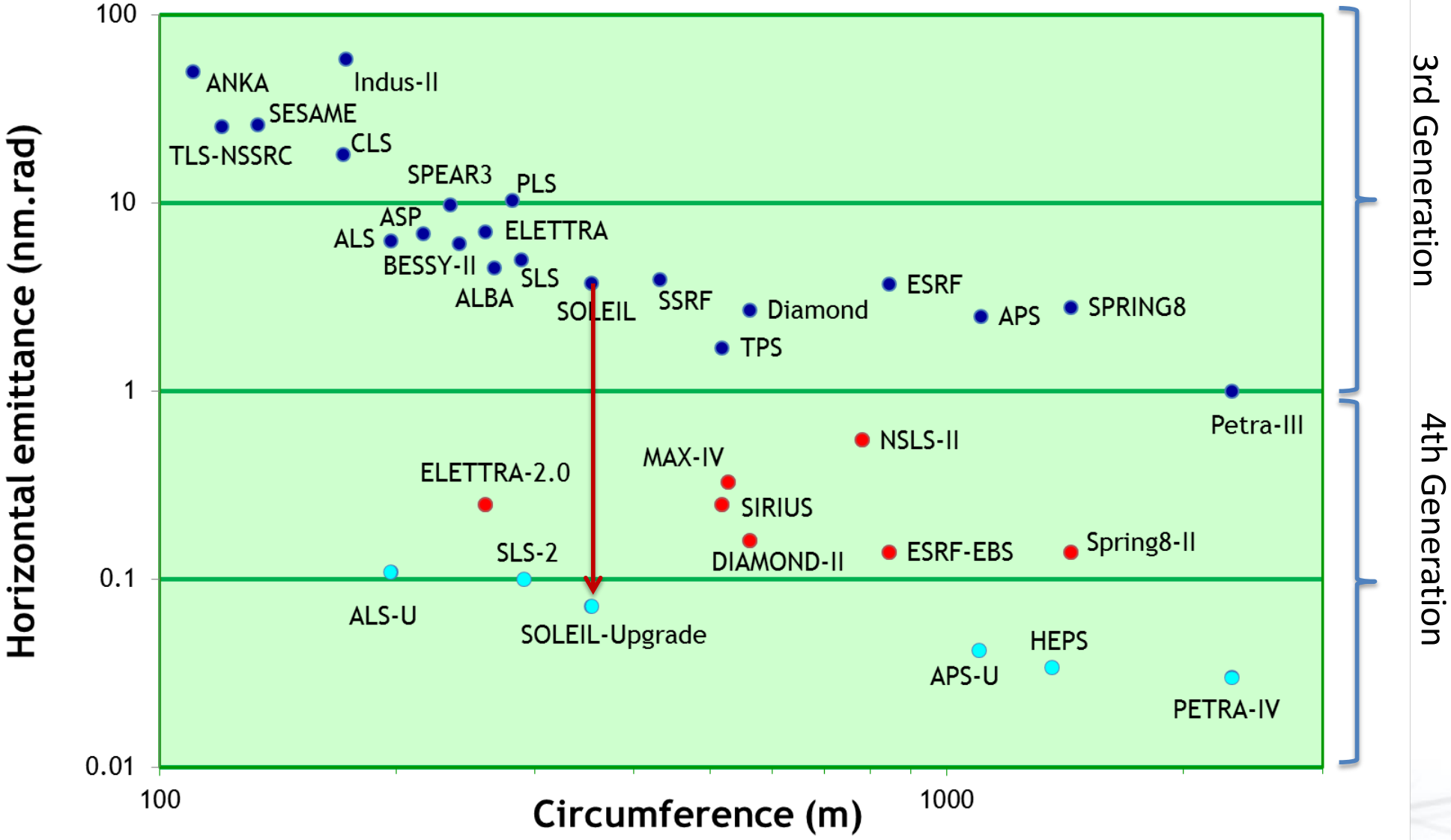
Reference:

R. Nagaoka, SOLEIL Upgrade,

8th Low Emittance Rings Workshop LER2020, INFN-LNF, Frascati, Italy, 26-30 October 2020

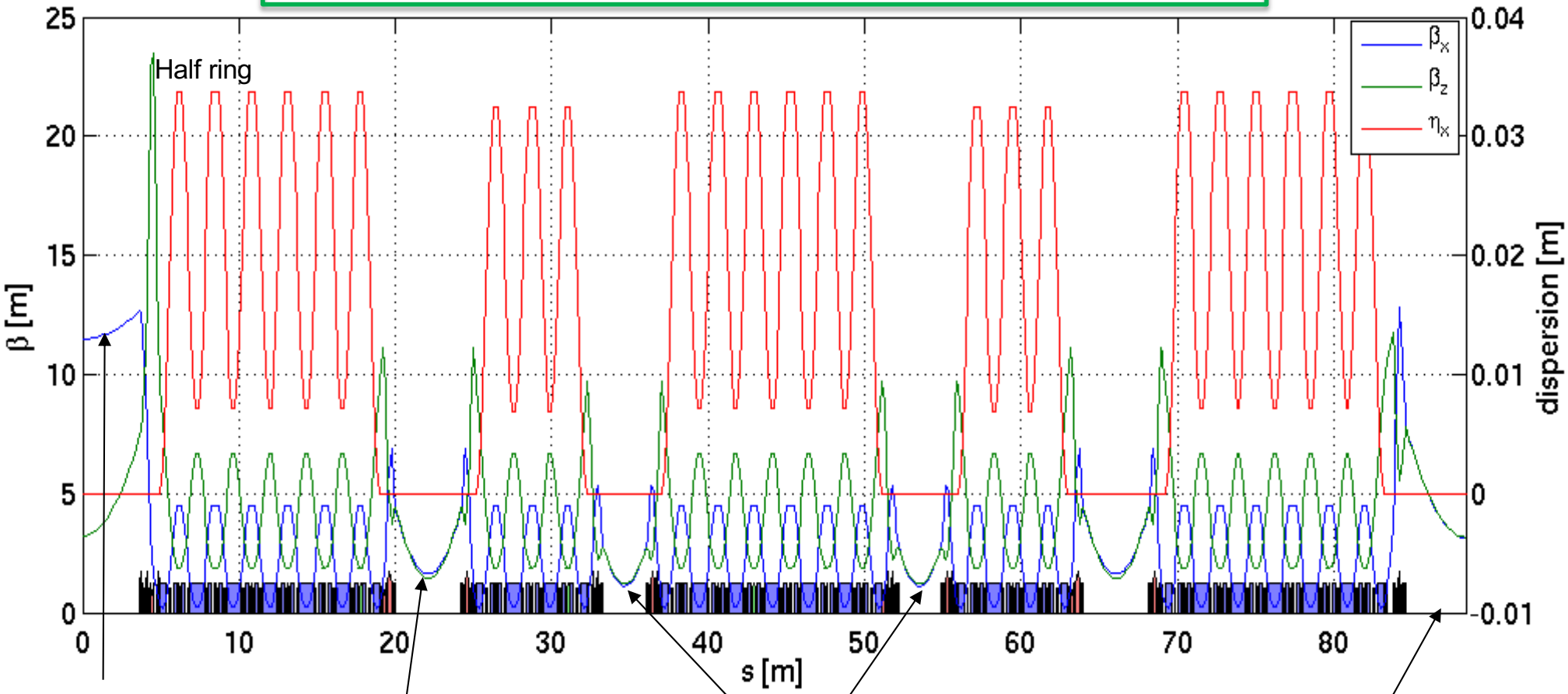
https://agenda.infn.it/event/20813/contributions/110195/attachments/76445/98315/SOLEILupgrade_LER2020.pdf

Emittance comparison for 3rd and 4th Generation Light Sources on Storage Ring



CDR Lattice Reference (V0313)

80 pm.rad 2.75 GeV 354 m 7BA - 4BA



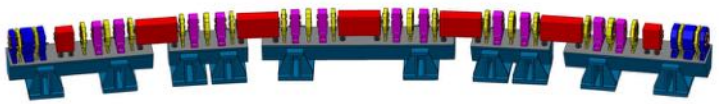
$Injection$
$\beta_x \sim 11m$
$L = 7.35m$

$\beta \sim 1.5m$
$L = 4.150m$

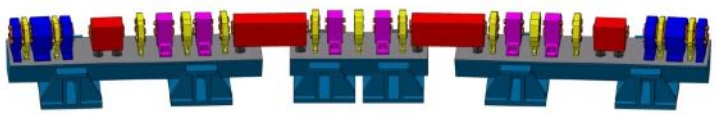
$\beta \sim 1.1m$
$L = 2.730m$

$L = 7.65m$
Chicane and quadrupole triplet to be added

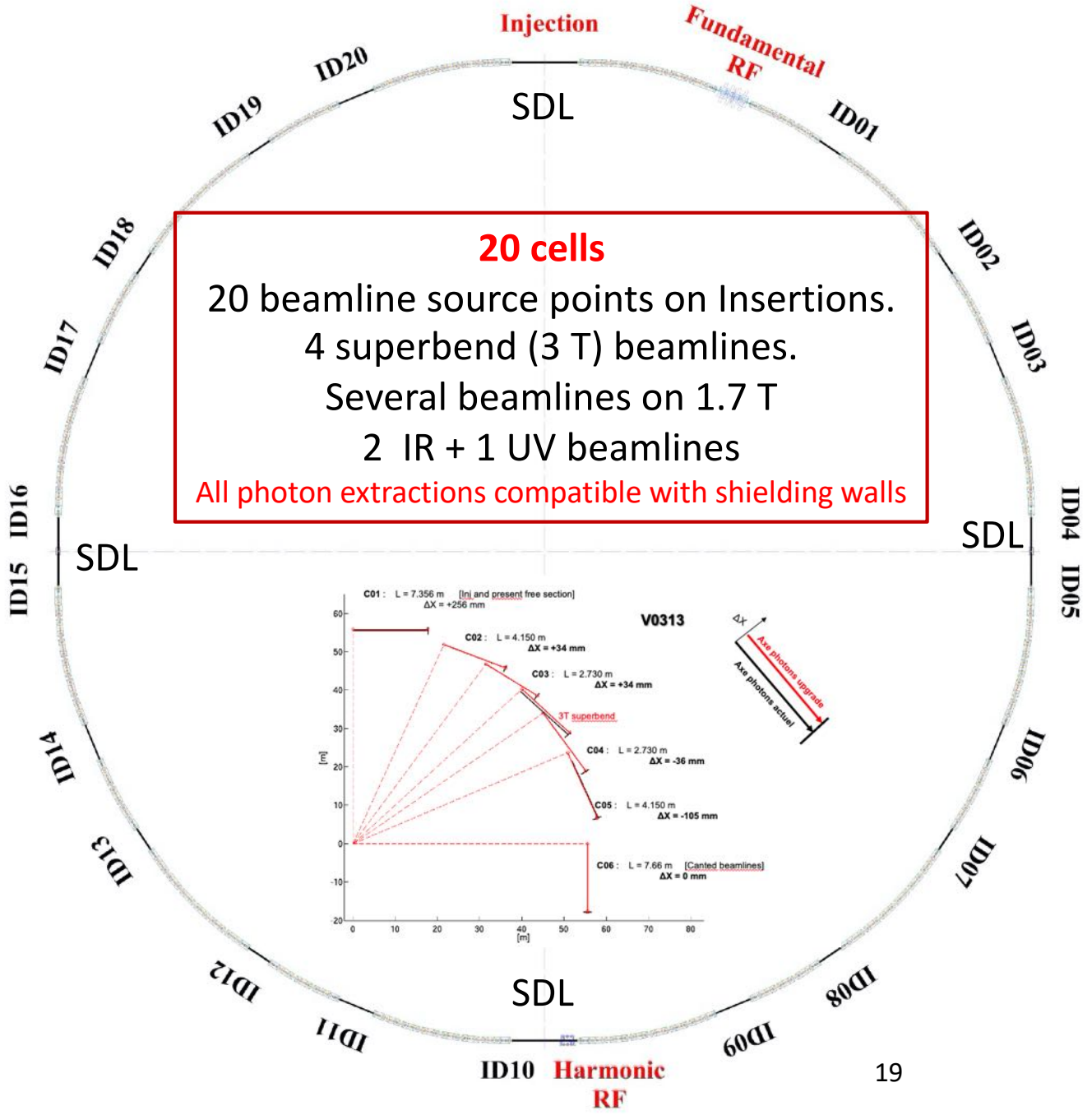
7 BA



4 BA



General Layout



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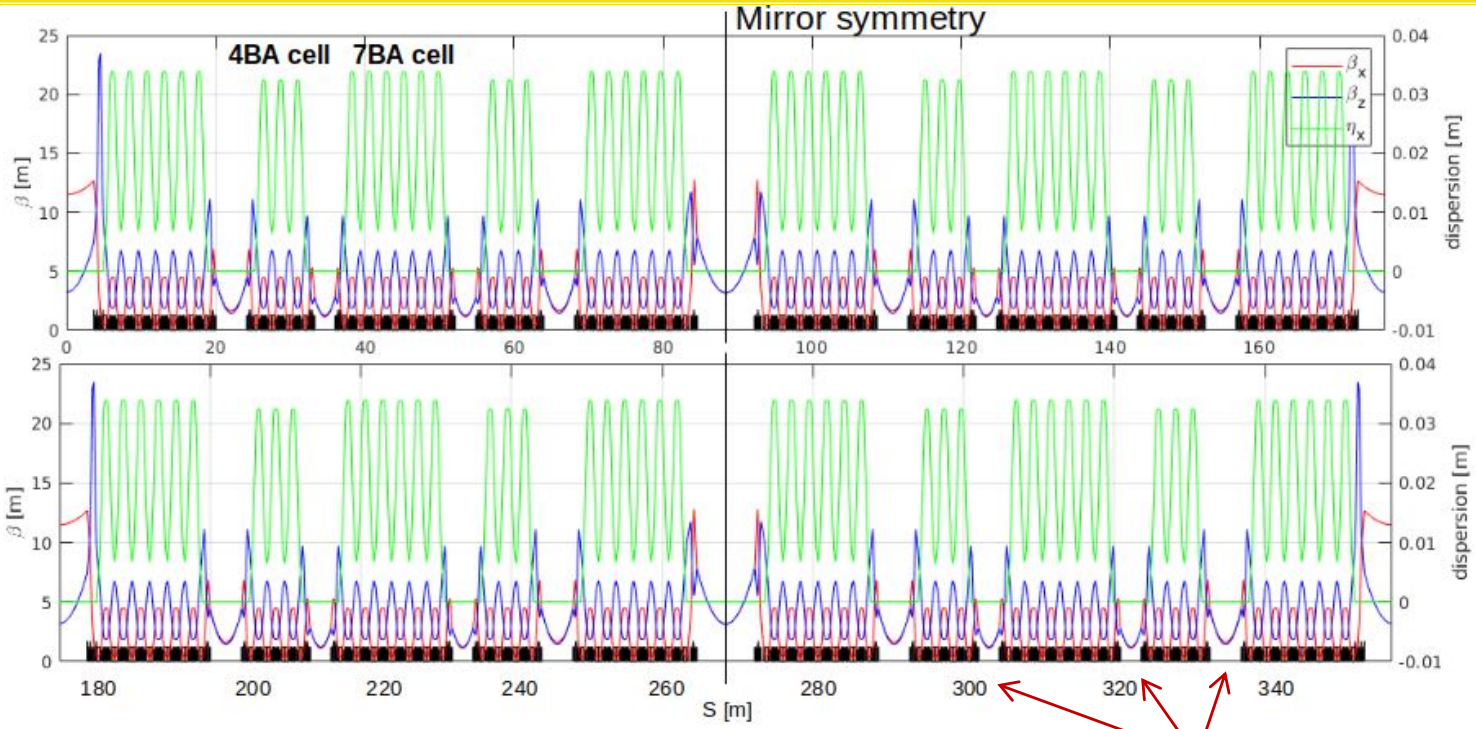
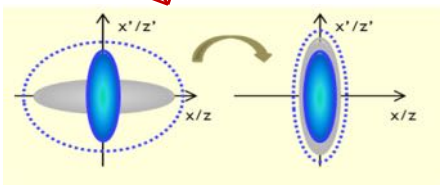
canted undulators

Present CDR reference lattice [1/3]

Entire layout of the CDR lattice: "HOA 7BA-4BA symmetry 2"



	L (mm)	B (T)	G (T/m)	No.	Tot	Location
Short bend 7BA cell	400	0.998	-8.013	24	40	Arcs dispersion
4BA cell	400	0.957	-8.013	16		suppressor
Long bend 7BA cell	947	0.696	-15.88	60	76	In the arcs
4BA cell	947	0.668	-15.88	16		
Rev bend 1 7BA cell	200	-0.210	56.34	120	152	In the arcs
4BA cell	200	-0.201	56.34	32		
Rev bend 2 7BA cell	200	-0.178	57.79	24	40	Arcs dispersion
4BA cell	200	-0.171	57.79	16		suppressor
Quadrupoles [B']	Various	-	≤ 110	144	144	Quadruplet in the straights
Sextupoles [1/2 B"] H&V correctors	60/80/110	-	8000 T/m²*	368	368	Both arcs and straights Combined magnet
Octupoles [1/6 B"'] Q correctors	50		3.10^5 T/m³*	176	176	Both arcs and straights Combined magnet
Total					996	

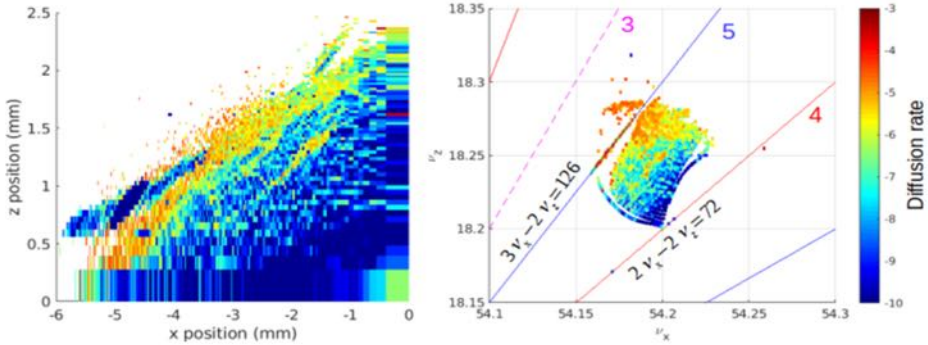


Main characteristics of the magnets used for the CDR lattice

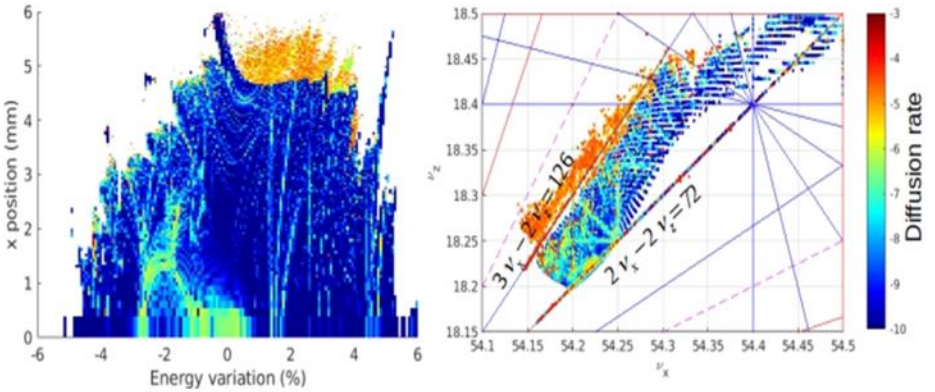
- **Permanent magnets** for dipoles and reverse bends
- Need of **strong** sextupoles and octupoles

Present CDR reference lattice [2/3]

Lattice		CDR lattice upgrade	Current lattice
Symmetry		2	1
Energy	[GeV]	2.75	2.75
Circumference	[m]	353.74	354.10
Straight ratio	[%]	24	46
Number of straight secs		20	24
RMS Natural H. emittance	[pm.rad]	81	4000
RMS Coupled H&V Emittance	[pm.rad]	53	
RMS Energy spread	[%]	0.09	0.10
RMS Natural Bunch length	[ps]	9.182	15.17
	[mm]	2.7	
Harmonic number		416	416
Main RF frequency	[MHz]	352.56	352.20
Energy loss per turn W/o ID	[keV]	490	917
RF Voltage	[MV]	1.38	2.9
Momentum compaction factor	[-]	9.12E-05	4.4E-04
Synchrotron frequency	[kHz]	1.4	4.5
	[turns]	600	190
Damping times (H/V/L)	[ms]	7.3 / 13.1 / 11.7	6.9 / 6.9 / 3.5
	[turns]	6000 / 11000 / 10000	5800 / 5800 / 2900
Nominal tunes (H/V/L)		54.2 / 18.2	18.16 / 10.22
Natural chromaticities (H/V)		-108 / -65	-53 / -19
Corrected chromaticities (H/V)		+1.6 / +1.6	+1.3 / +2.2



On-momentum Frequency Map Analysis (FMA) at injection point



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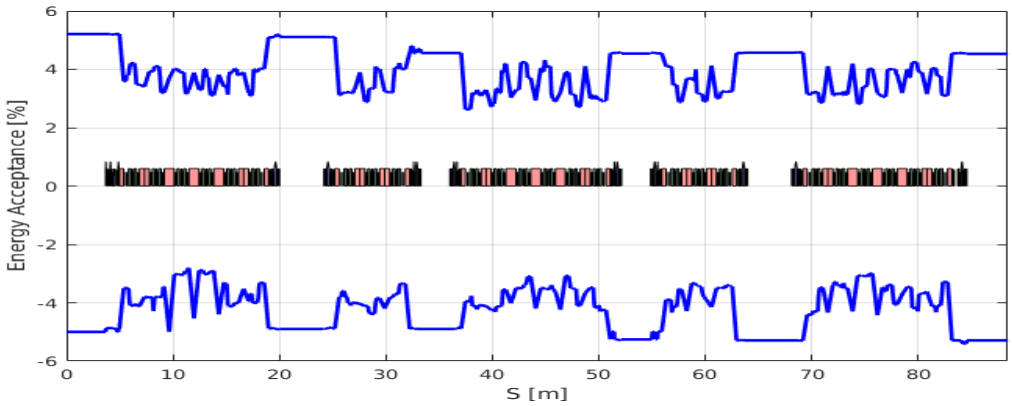
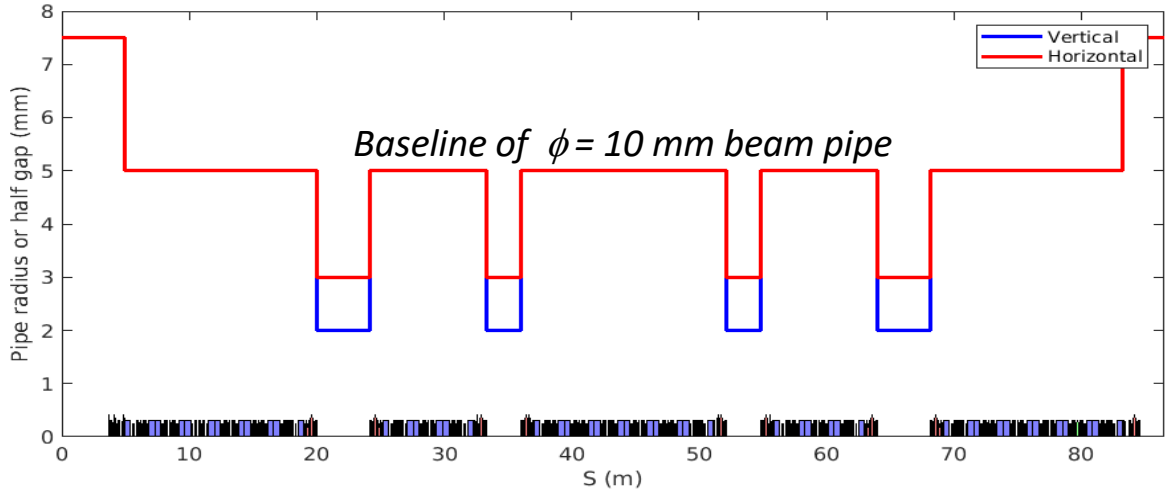


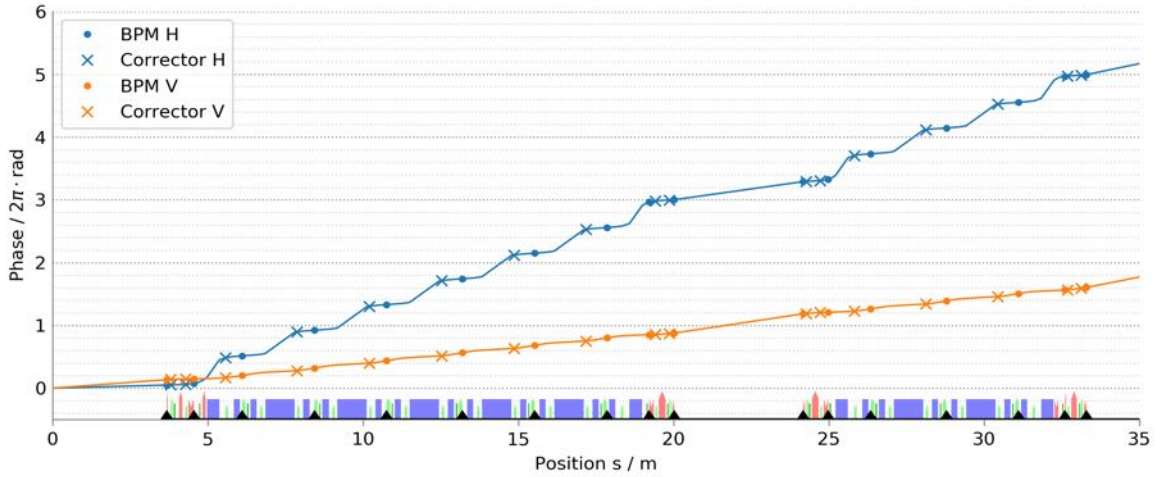
Left: Local energy acceptance along ¼ ring

$\tau_{Touschek}$ *at 500 mA:*
~3.5 hours ***100% coupling***
~1.5 hours 10% coupling
w/o bunch lengthening

Present CDR reference lattice [3/3]



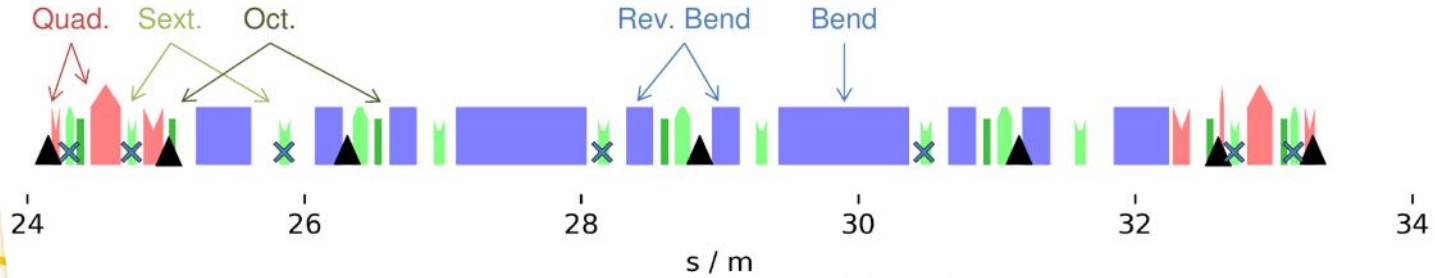
Half physical aperture along the ring including in-vacuum insertion device gaps



Studies of

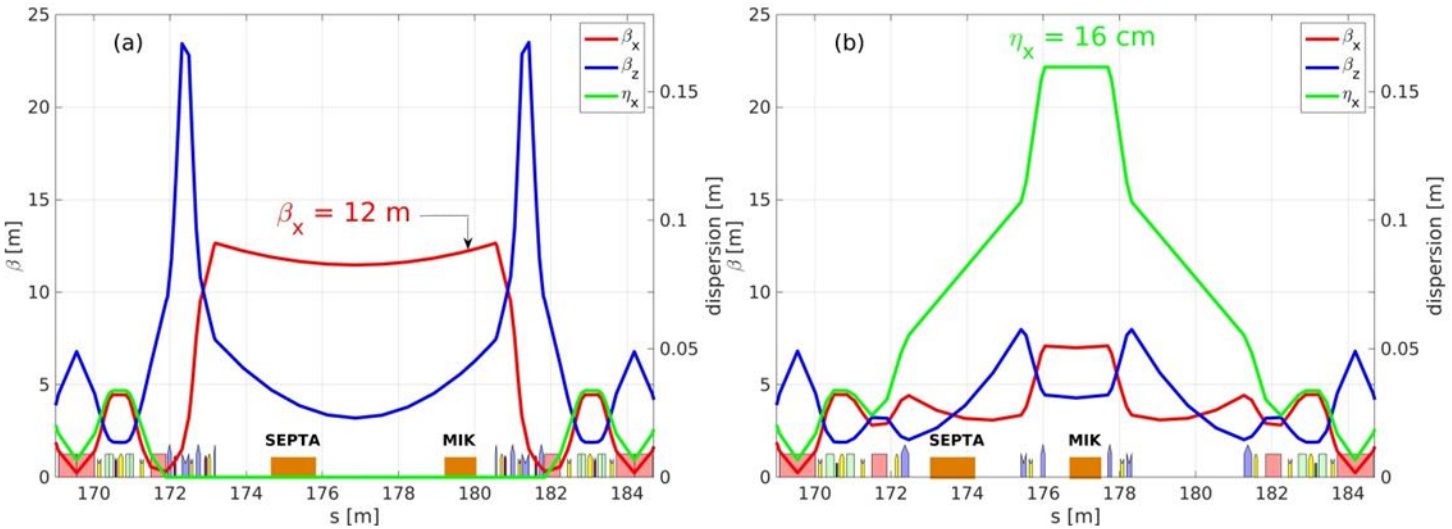
- Lattice tuning flexibility
- 1st-turn steering
- Robustness against errors

launched with specific BPM-correctors (dipolar, normal and skew quadrupolar) configurations



Top-up Injection schemes developed [1/2]

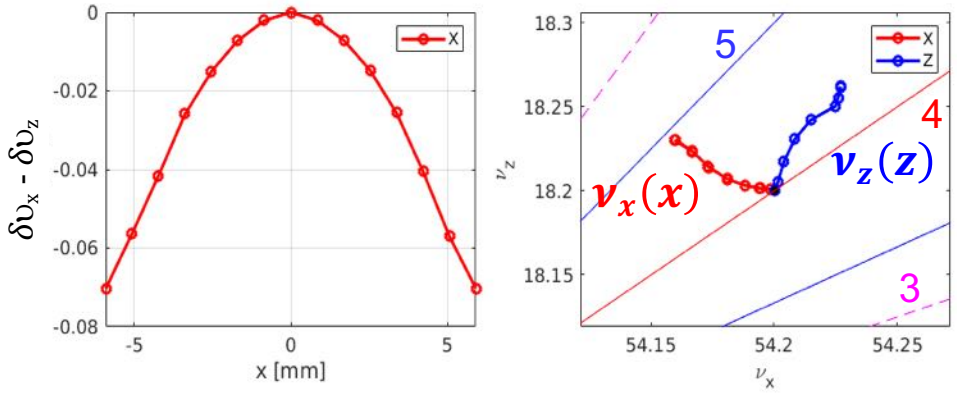
- **Two injection schemes** are developed and studied at SOLEIL using a **MIK (Multipole Injection Kicker)**, with the experience of developing one which gave success at MAX-IV: "**betatron off-axis**" and "**synchrotron on-axis**" injections



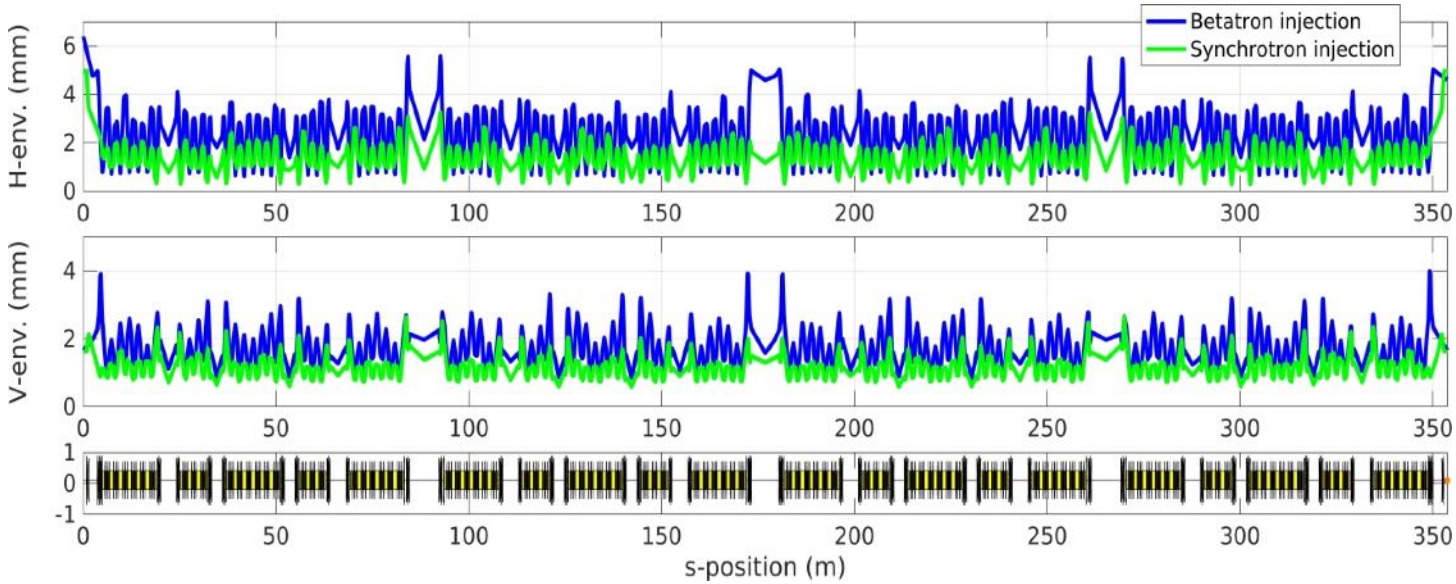
- In both cases, MIK deflection at Δx **= -3.5 mm** from the stored beam location
- Injected beam at δ **= -2%** for synchrotron on-axis injection

***Left**: Horizontal beta bump for betatron off-axis injection with tunes (54.20, 18.20). **Right**: Horizontal dispersion bump for synchrotron on-axis injection with tunes (54.16, 18.16)*

- In both schemes, beam is injected to a ring tuned to **a coupling resonance** and the stored beam is **fully betatron coupled**
- In **betatron off-axis injection**, nonlinear tune shifts with amplitude are adjusted to enable "***dissonance***" for the injected beam



Injection schemes developed [2/2]



H and V beam envelopes over 900 turns after injection for both injection schemes, w/o error at injection nor in storage ring. Ring working point is set at full coupling. $(\varepsilon_H)_{inj} = (\varepsilon_V)_{inj} = 5$ **nm.rad**, σ_L = 25 ps for betatron and 35 ps for synchrotron injections

	Positive aspects	Negative aspects
Betatron off-axis	• Allow straightforward implementation in injection straight • Pulse magnets specs comfortable	• Sensitivity to lattice errors • Need of a large DA • Injection beam envelops have smaller margins against ID gaps
Synchrotron on-axis	• Relaxed DA requirement • Less sensitivity to lattice errors • Reduced injection beam envelops	• Explicit lattice modifications with a dispersion bump • Need of larger off-momentum DAs • More demanding MIK specs

⇨ **Both schemes to be pursued further**

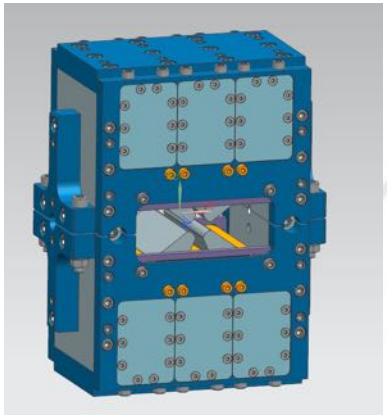
Magnet Prototypes

Quadrupole = 140 T/m (7 X today) Sextupole = 8000 T/m² (25 X today)

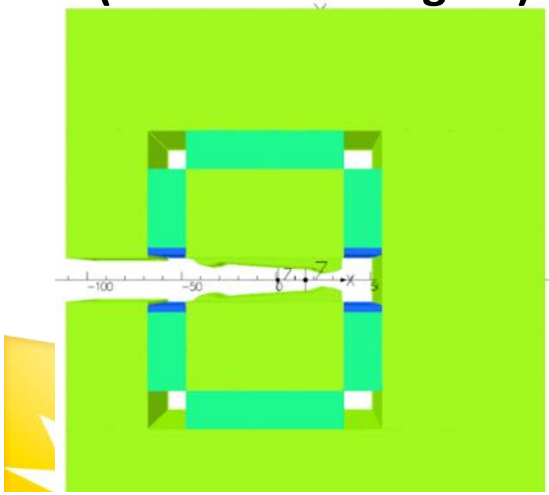
Extensive use of permanent magnets

➢ Quadrupole

- Procurements by the end of 2020
- In-house assembly by the end of 2020
- Magnetic measurements First semester of 2021

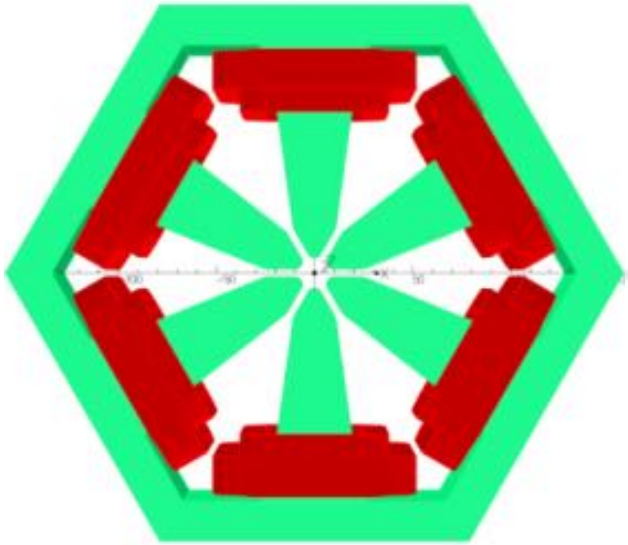


➢ Combined dipole (Permanent magnet)



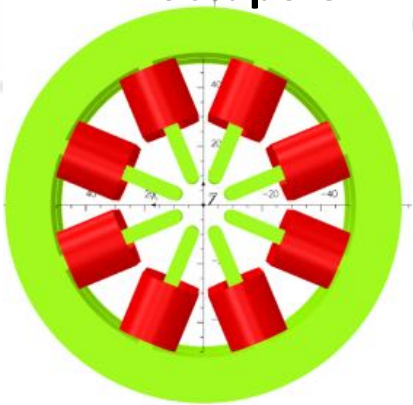
- Assembly and magnetic meas. Mid 2021

➢ Multipurpose sextupole



- Assembly and magnetic meas. Mid 2021

➢ Multipurpose octupole

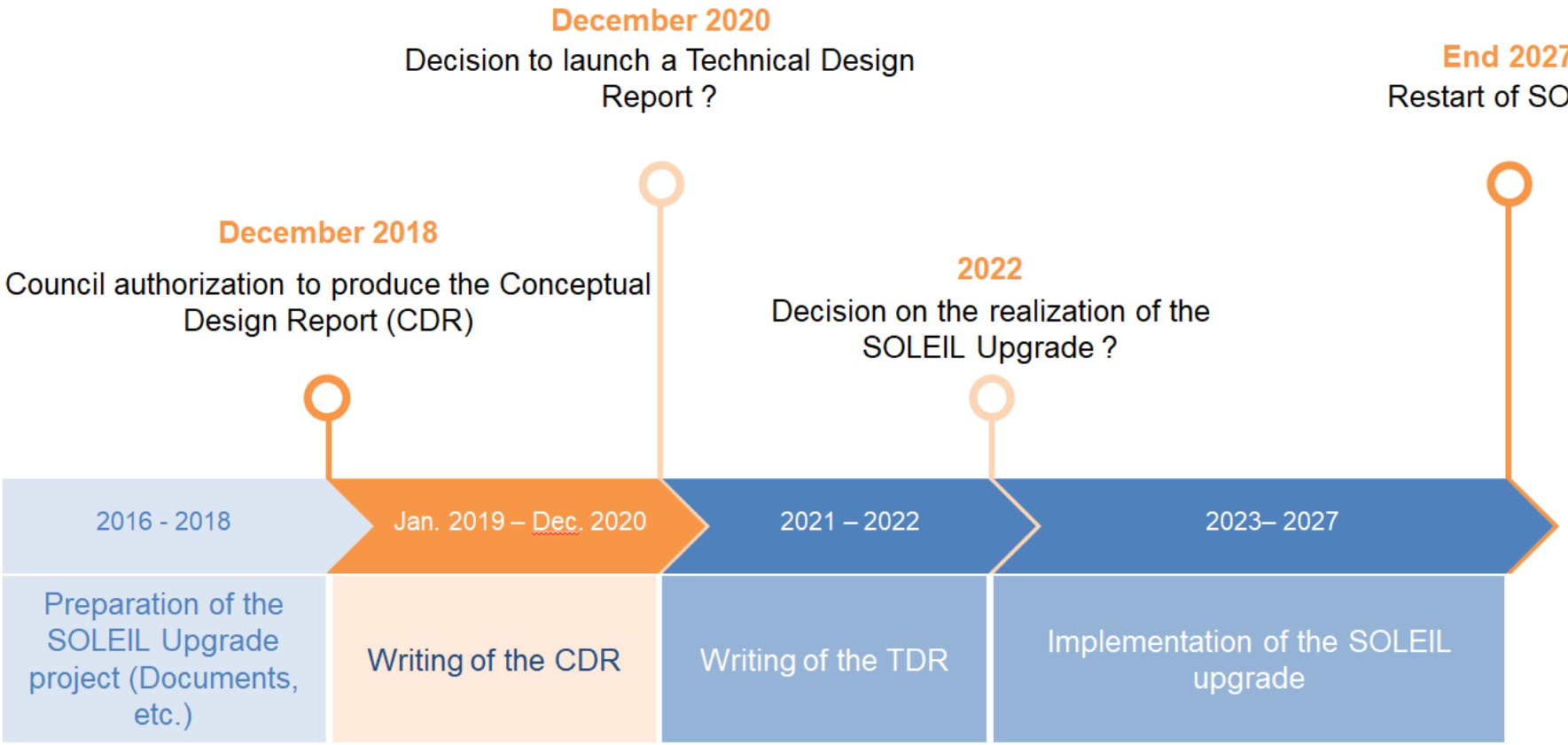


- Assembly and magnetic meas. Mid 2021

Main CDR Milestones

- 4 reviews held during the last 6 months
  - Ultra-vacuum system review (11-12 June 2020)
  - Magnet Review (2-3 July 2020)
  - Lattice and Injection Review (7-8 September 2020)
  - Girder Review (17-18 November 2020)
- SOLEIL SAC (16-17 November 2020)
- SOLEIL council (14 December 2020)
- Mini-MAC to close the CDR phase (February 2021)

Tentative Planning and Objectives



Conclusions

- Despite a very special year due to CoViD-19 crisis
  - Operation with extremely good performance (7 weeks operation lock-down)
  - All 29 beamlines work 24/7
  - Small delays concerning major projects of the accelerators

- Upgrade
  - Ending the CDR period:
    - a first strong lattice candidate answering major criteria (performance, impact on shielding, number of BLs)
    - A strong scientific case
  - Preparing TDR phase
    - Entering prototyping phase (magnet, vacuum, girders, injection, diagnostics, RF-system, insertion devices, etc.)
    - **Critical phase for the mechanical integration**, extraction of the photo beams, etc.
    - Robustness and tuning capability of the lattice
    - Choice of ex/in situ backing out, NEG and pumping capacity of 6-10 mm diameter chambers
    - New Booster design
    - …

Questions ?

Acknowledgments

- A. Nadji, R. Nagaoka
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- Accelerator Physics Group