Introduction to the SOLEIL II Project

27 February 2025, R. Nagaoka, at PSI, Villigen, Switzerland

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Outline

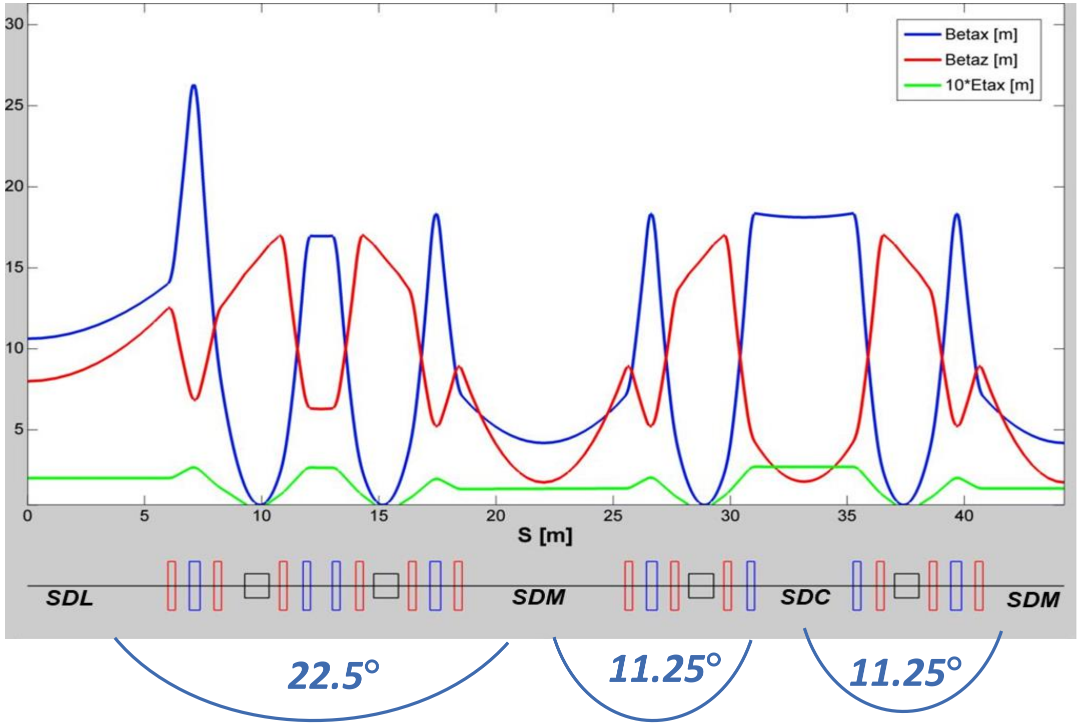
1. **SOLEIL II Project: Its objective, constraints and early development**
2. **Developed SOLEIL II TDR solution, its characteristics and challenges**
3. **Major project timeline and milestones**

1. SOLEIL II Project: Its objective, constraints and early development

1.1 Objectives set up at an early stage of the project

- **Reduce** by more than a factor 30~40 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 point positions
- **Keep** the storage ring energy commensurate with a very broad photon energy range
- **Preserve** a current of 500 mA in multibunch operation
- **Preserve** time structure and time resolved operations
- **Reuse** of the injector complex: Linac and booster
- **Reuse** much of the technical infrastructure
- **Limit** downtime to a maximum of two years
- **Minimize** operation costs, in particular the wall-plug-power
- **Preserve** Infra-Red (IR) beamlines.
- **Provide** alternative radiation sources for the existing bending magnet based beamlines

1.2 SOLEIL ring today with its boundary conditions (1/2)



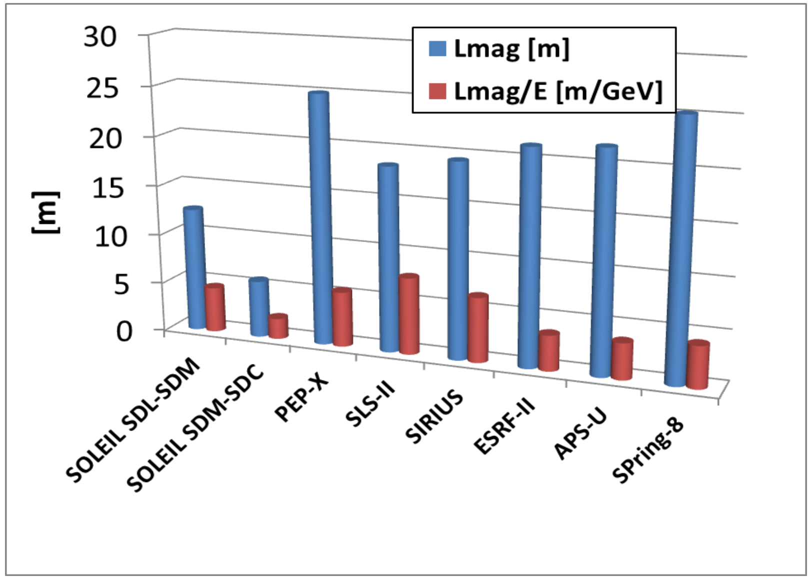
1/8th of the present SOLEIL lattice

Energy	2.75 GeV
Circumference	354.097 m
Lattice type	Double Bend
Number of cells	16
Number of straight sections	4×12 m, 12×7 m, 8×3.8 m
Magnet sections length	8×12.5 m, 16×5.73 m
Ratio of straight sections length to circumference	46%
Horizontal natural emittance ε_x	3.91 nm·rad
Adjusted emittance ratio	1%
Betatron tunes (ν_x, ν_z)	(18.17, 10.23)
Natural chromaticities (ξ_x, ξ_z)	(-52.55, -21.24)
Momentum compaction	4.49×10^{-4}
RMS energy spread	1.016
Horizontal damping partition number J_x	0.9953
Radiation damping times (τ_x/ τ_z/ τ_s)	(6.92/6.88/3.43) ms
Dipole field	1.71 T
Radiation loss per turn (w/o IDs)	943.8 keV
Nominal current	500 mA (multibunch mode), 450 mA (hybrid mode), 8×12 mA (8-bunch mode), 1×16 mA (1-bunch mode)
RF frequency f_{RF}	352.2 MHz
RF voltage (typical)	4× 650 kV

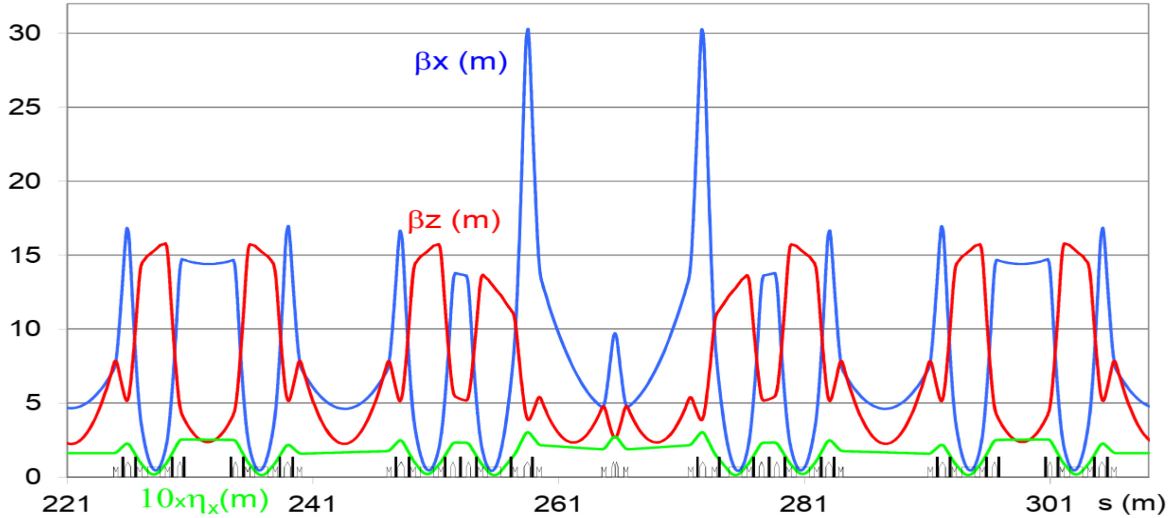
Major characteristics of the present SOLEIL ring (a 16 Double Bend cell ring)

- Half of them integrates a SS (Straight Section) of 3.8 m in between the two dipoles
- Long SS of 12 m introduced symmetrically at 4 locations
- Ring's original symmetry: Four with 24 SSs (consisting of 3 different lengths):
- Beam filling: Four modes including multibunch at 500 mA and a single bunch at 16 mA

1.2 SOLEIL ring today with its boundary conditions (2/2)



- SOLEIL ring is considered to be the most optimised ring in the LS community in terms of ratio = (sum of SS length) /Circumf, attaining the record value of **46%**
- As a result, the magnet sections are intrinsically short, particularly in between SDM and SDC

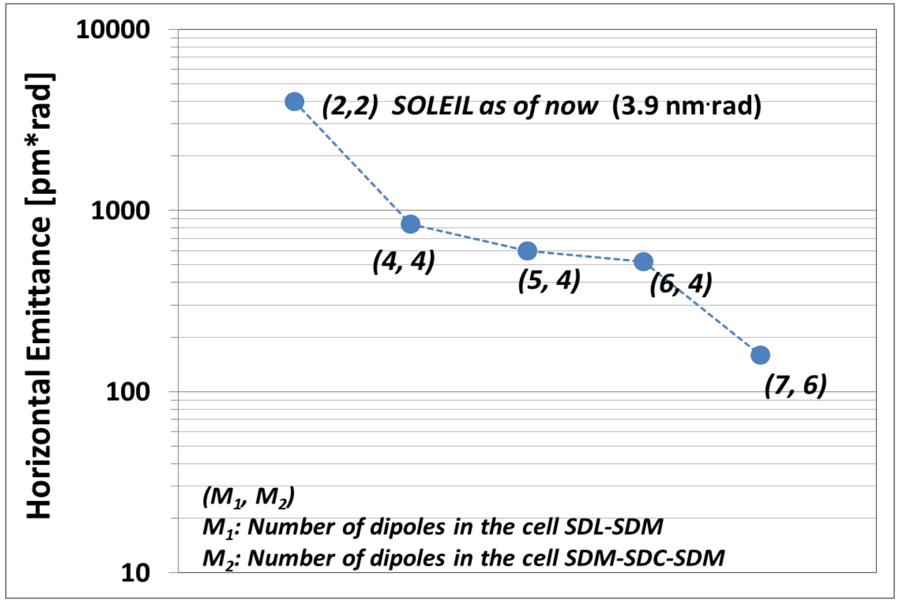


- Canting and double waist optics introduced in one of the four SDLs reduced the ring symmetry 1 ⇨ SOLEIL has been operating a **symmetry 1 ring since 2011**

Introduction of double waist optics in one of the four long straight sections (SDL13) for two long BLs (NANOSCOPIUM and ANATOMIX), reducing the ring symmetry to 1

1.3 A series of upgrade lattices studied in the past

Lattice	ε_{H0} [pm]	Conference
4BA using LGBs (24 existing straight sections non-altered)	980	IPAC2012
5BA-4BA (24 existing straight sections non-altered)	520	IPAC2013
5BA-4BA (24 existing straight sections non-altered)	440	IPAC2014
7BA-6BA using LGBs (24 existing straight sections non-altered)	145	IPAC2015
7BA-6BA using RBs (24 existing straight sections quasi non-altered)	206	IPAC2016
7BA-6BA using the ESRF hybrid type lattice (24 existing straight sections kept but shortened)	220	IPAC2017
20×(7BA ESRF hybrid type lattice)	72	IPAC2018
20×(7BA Higher-Order Achromat lattice)	76.5	IPAC2019



$$\varepsilon_x^{TME} = \frac{1}{8\sqrt{15}}\frac{C_q\gamma^2}{J_x}\theta_0^3\cdot\left\{\frac{1}{\left[2+(M_1-2)3^{1/3}\right]^3}+\frac{1}{\left[2+(M_2-2)3^{1/3}\right]^3}\right\}$$

An approximate formula for TME in a ring composed of alternating M_1BA and M_2BA cells.
θ_0 : Total bending angle per cell

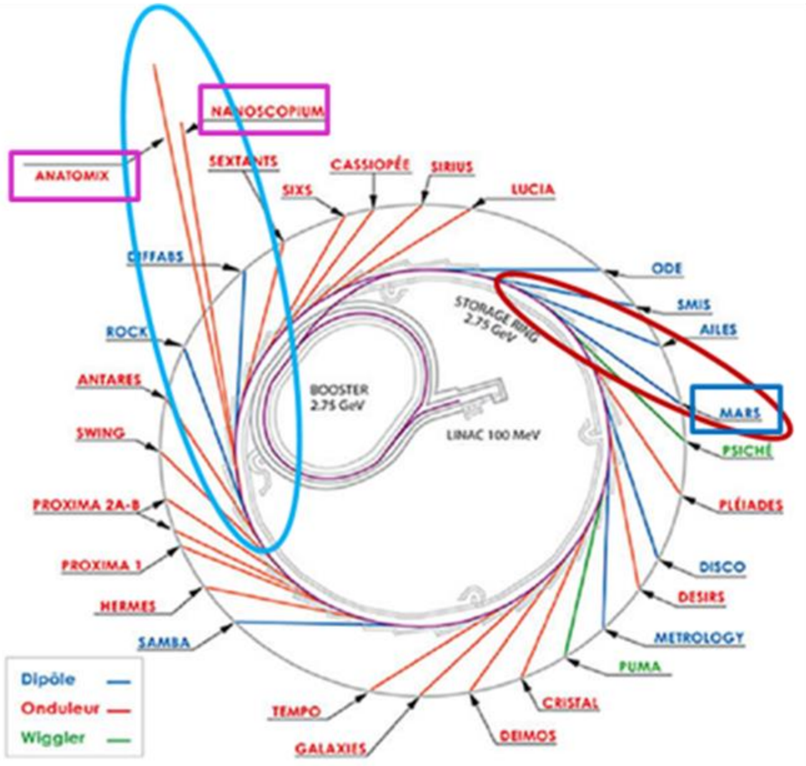
1.4 Boundary conditions set by management in 2018

1st step: Symmetrize the ring with **20 identical cells** and straight sections of longer than **4 m** and explore the performance of symmetric MBA lattices

cf) $(20/16)^3 = 1.95$

2nd step: Accept symmetry reduction **20 → 4** to integrate the following additional constraints:

- Geometry of the new lattice must allow
  - Keeping the source point of **MARS BL** (treating radioactive sources) unchanged
  - **Two long BLs NANOSCOPIUM and ANATOMIX** to conserve their current hutches by using new canted in-vacuum IDs with shorter magnetic periods
- **Two infrared BLs** are envisaged of which one dedicated towards the longest possible wavelengths
- Very low energy photons (of the order of 2 eV) from an exit of a dipole and an ID (5 eV) allowing the different polarisations used currently
- At least **four dipole BLs** shall have "**superbends**"
- Impact on the positions of other existing BLs must be minimised as much as possible



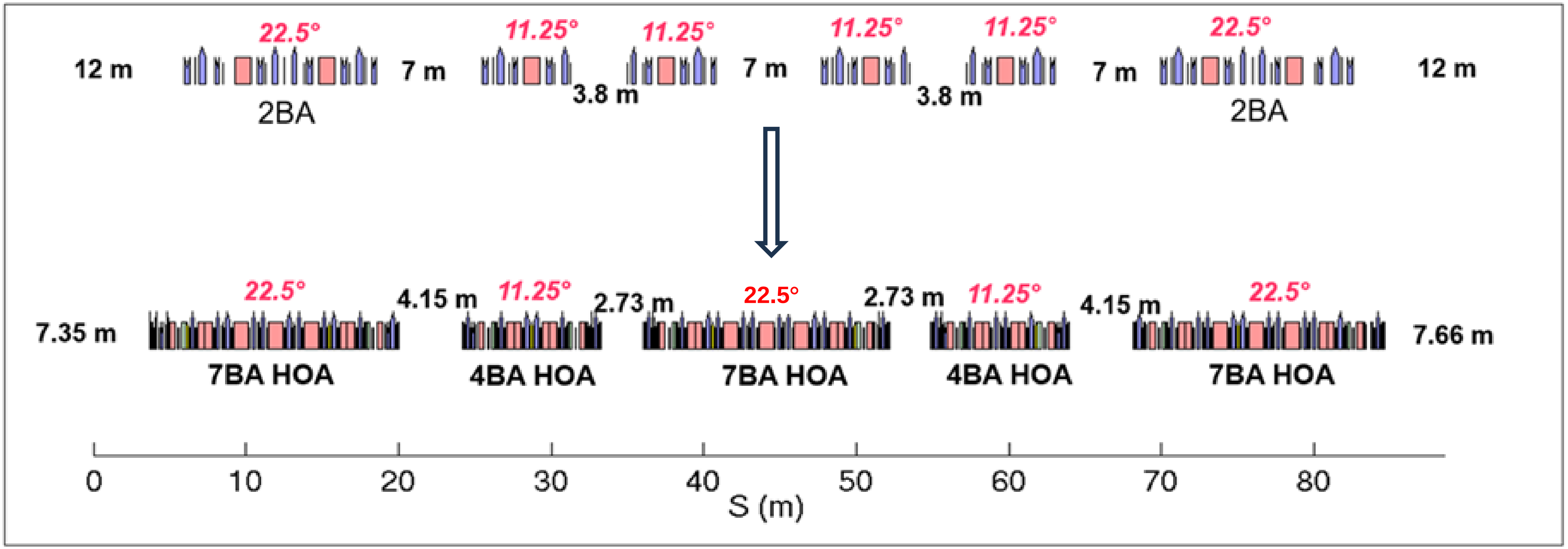
1.5 7BA-4BA HOA lattice to overcome the geometric mismatch

- During the CDR phase, a **symmetry-4** 20-cell 7BA ***hybrid*** lattice **with 4×6 m + 16×4 m** straight sections designed (ε_x = 74 pm.rad, τ_{Touschek} = 1.8 h)

However, mechanical engineering studies revealed that there are yet 6 to 8 shielding ratchet walls and as many BLs (out of 24) that are geometrically in serious mismatch

⇨ Using the "***modularity***" of **HOA cells**, studies launched to explore a **20 cells *M*BA-*N*BA HOA** that best matches the geometric constraints and fulfils the performance requirements

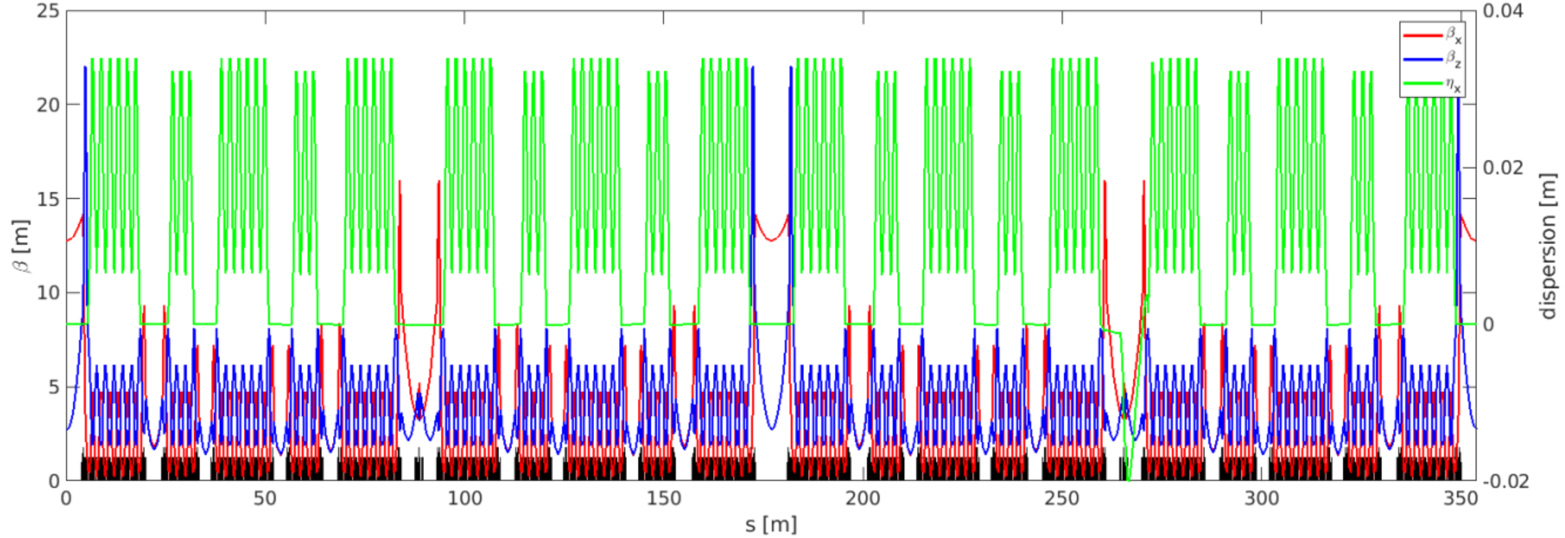
⇨ **A 20-cells 7BA-4BA HOA lattice** designed during the CDR phase as the SOLEIL upgrade reference lattice



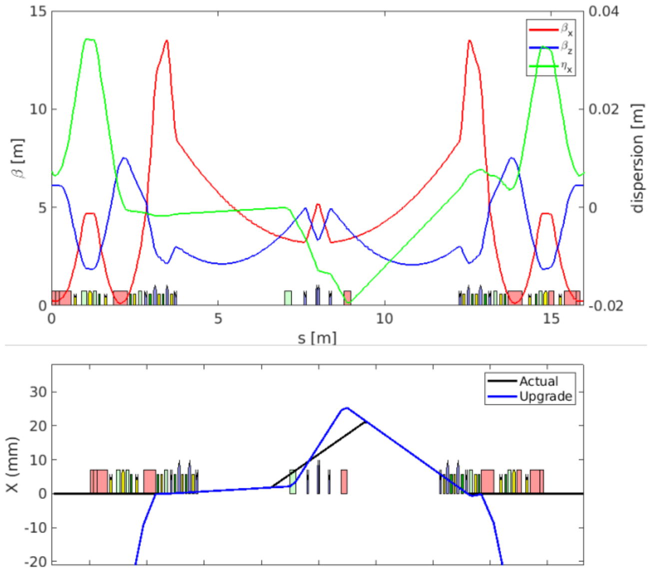
Relation between the present ring and 20 cells 7BA-4BA HOA created during the CDR phase for 1/4th of the ring

2. Developed SOLEIL II TDR solution, its characteristics and challenges

2.1 Major ring parameters and performance (1/2)



Optical functions of the 7BA-4BA SOLEIL II lattice producing $(\varepsilon_H)_{natural}$ = 85 pm.rad

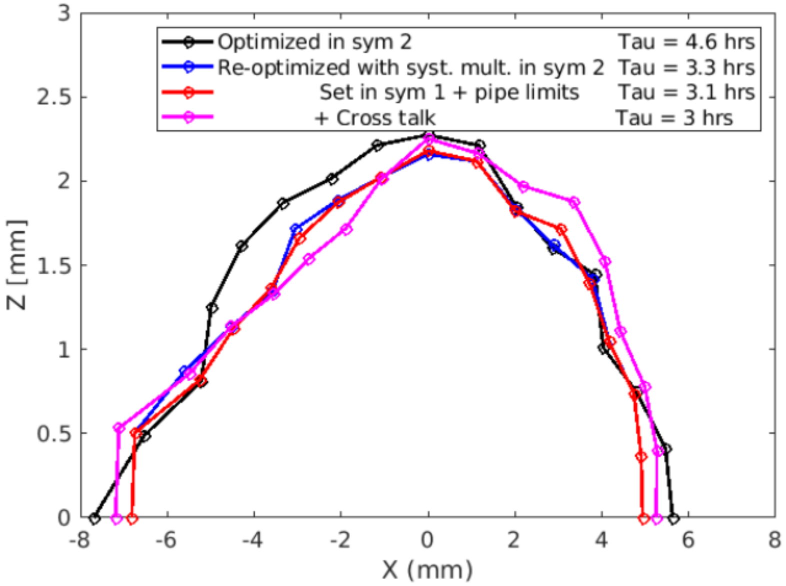


Double low beta optics for the ***two canted long beamlines*** *(top) and comparison of the SOLEIL II horizontal trajectory with the actual one (bottom)*

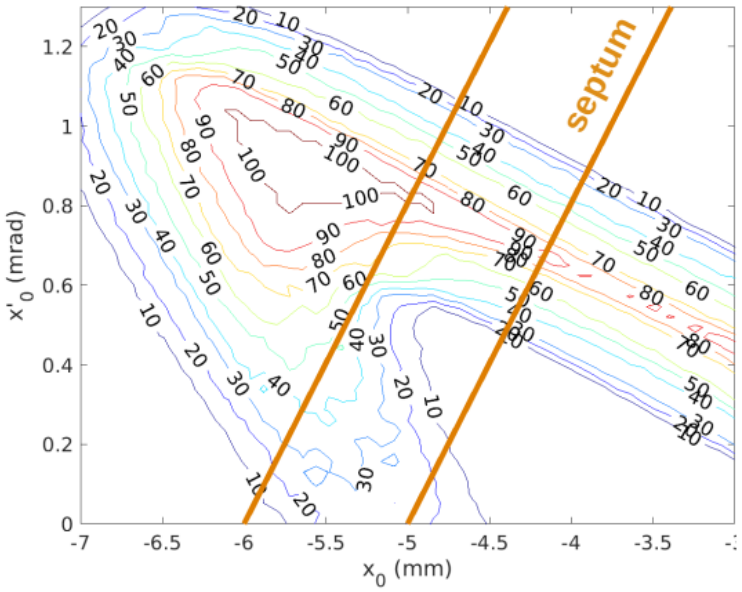
	Present	SOLEIL II
H-Emittance (2.75 GeV)	4 nm.rad	85 pm.rad
Circumference	354.10 m	353.96 m
Straight section number	24	20
Long straight length	12.00 m	8.07 / 9.00 m
Medium straight length	7.00 m	3.71 / 4.21 m
Short straight length	3.80 m	3.14 m
Straight length ratio	46 %	25 %
Betatron tunes H/V	18.16 / 10.2	54.2 / 18.3
Mom. comp. factor	4.18$10^{-4}$	9.9 10^{-5}
RMS energy spread	0.102 %	0.095 %
Energy loss per turn	917 keV	477 keV
Damping times s/x/z (ms)	3.3/3.3/6.6	7.4 /13.5 /12.1
RMS Nat. bunch length	15.2 ps	8.9 ps
RF main cavity voltage	2.8 MV	1.7 MV

Main bare lattice parameters in comparison with those of the present ring.
Envisaged beam fillings: 500 mA in the uniform mode and 200 mA in 32-bunch mode

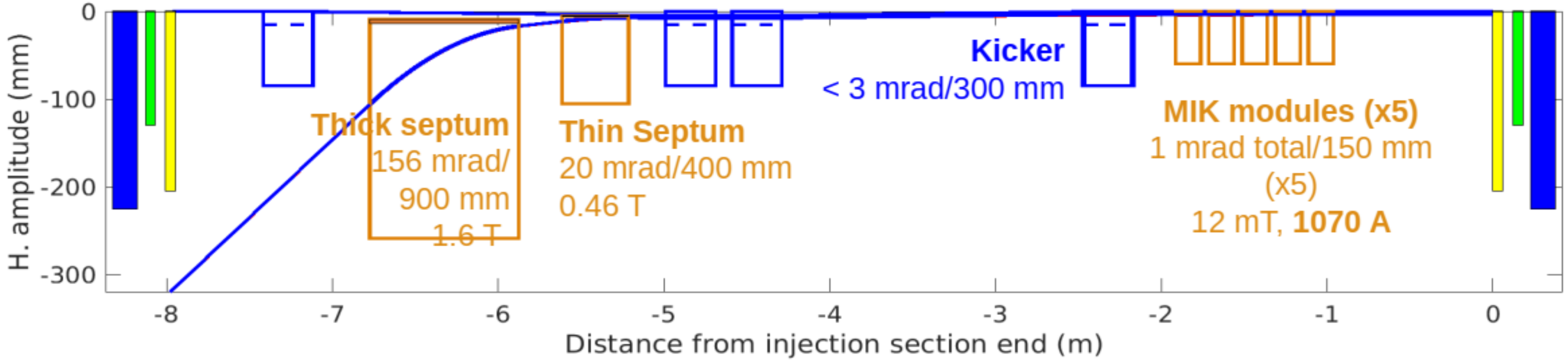
2.1 Major ring parameters and performance (2/2)



DAs and $(\tau)_{Touschek}$ versus the lattice settings.
$(\tau)_{Touschek}$ is calculated for 500 mA beam with 30% emittance coupling (25 pm vertical emittance) without bunch lengthening



Simulated off-axis injection efficiency using a MIK into an ideal ring (symmetry one) w/o errors



Ring injection layout
Including the 4 additional kickers

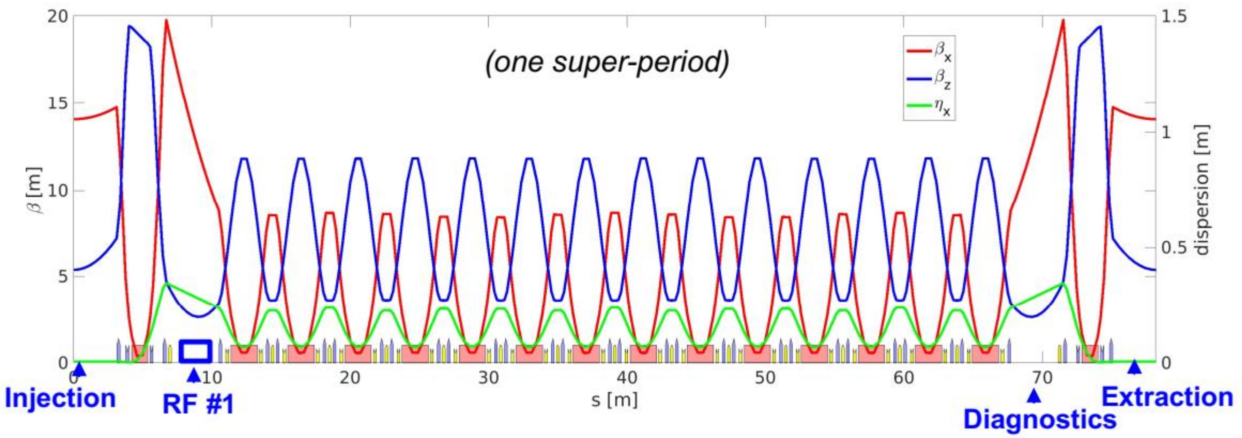
Three injection schemes are foreseen: On-axis using a single kicker; Off-axis using 4 kickers; Off-axis using a MIK

2.2 Overall accelerator complex and its upgrade

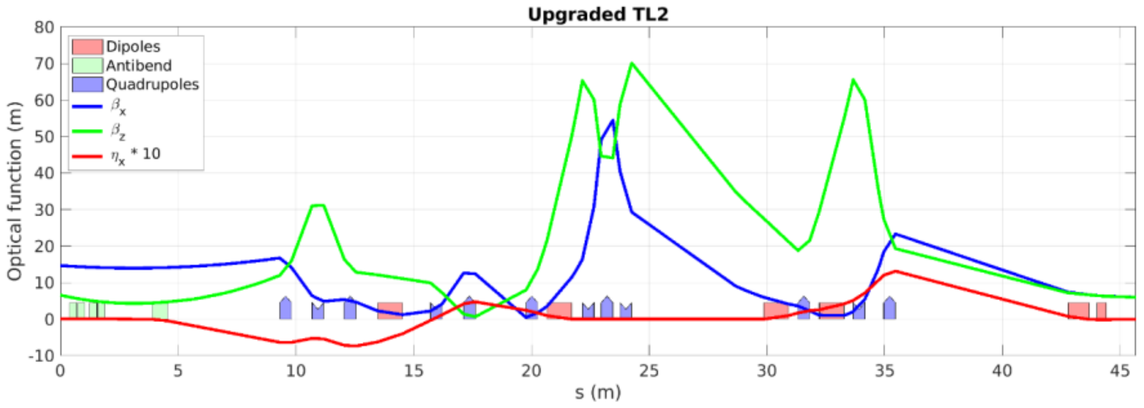
❑ Motivation for a LINAC upgrade:

The increase of the **injected beam energy** into the booster from 110 to **150 MeV** can only be a favorable option, in terms of :

- Remanent field in the booster magnets (dynamic range $E_{extr.} / E_{inj.}$ decreasing from 25 to 18.3).
- Reduction of the geometric emittance of injected beam scaling with $1/\gamma$ (factor 0.7).
- Eddy current sextupolar component in booster dipole (see example)
- Gas lifetime (elastic scattering) scaling with γ^2 (factor 1.8)



A 16BA lattice based on a combination of three HOA type 5BA cells, in which the Hor and Ver phase advances of each unit HOA cell are (0.3965, 0.1044)·2π.



Upgraded design of a booster-to-storage ring transferline with a dispersion-free section to measure the emittances of the booster beam

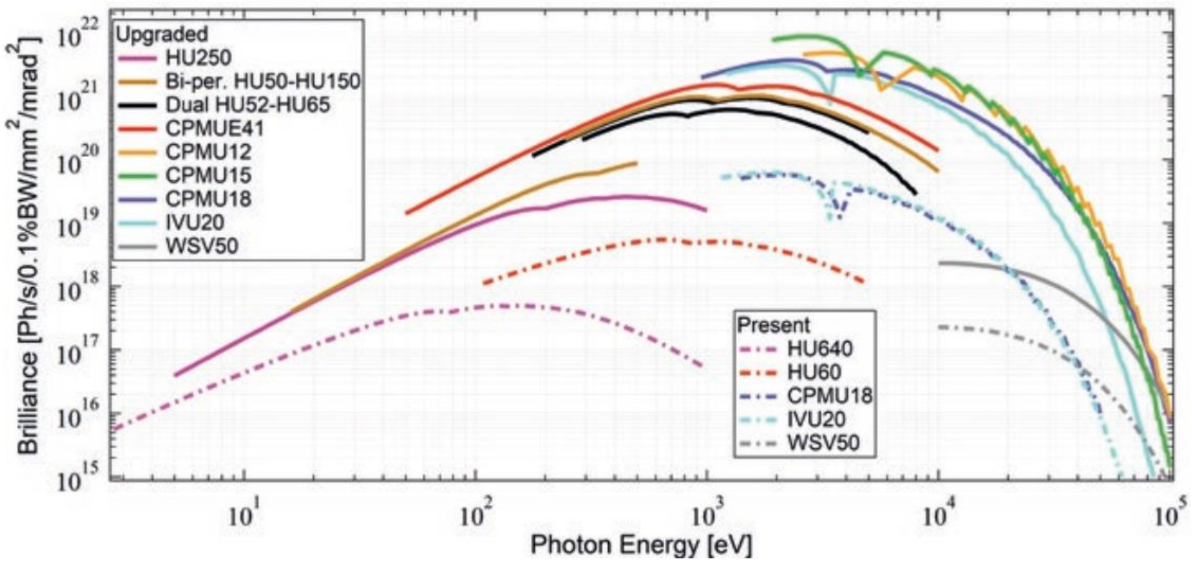
Parameter	Unit	Designed booster
Circumference	m	156.46
Natural emittance	nm.rad	5.2
Betatron tunes	-	13.19, 4.19
Natural chromaticities	-	-27, -12
Mom. comp. factor	-	$3.3 \cdot 10^{-3}$
Damping partitions	-	1.58, 1.0, 1.42
Natural damping times	ms	3.3, 5.2, 3.7
Energy loss per turn	keV	554
Natural energy spread	-	$0.93 \cdot 10^{-3}$
RMS bunch length	ps	25 @ 3 MV

Main parameters of the upgraded booster.

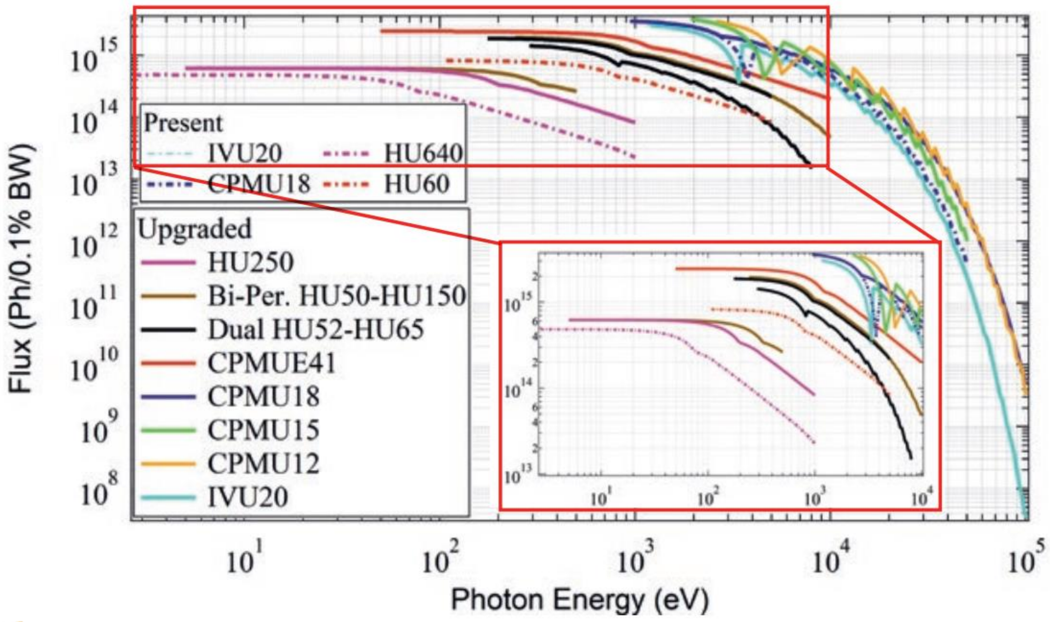
Emittance exchange using a pulsed skew quad is foreseen

2.3 Targeted light source performance and foreseen IDs (1/2)

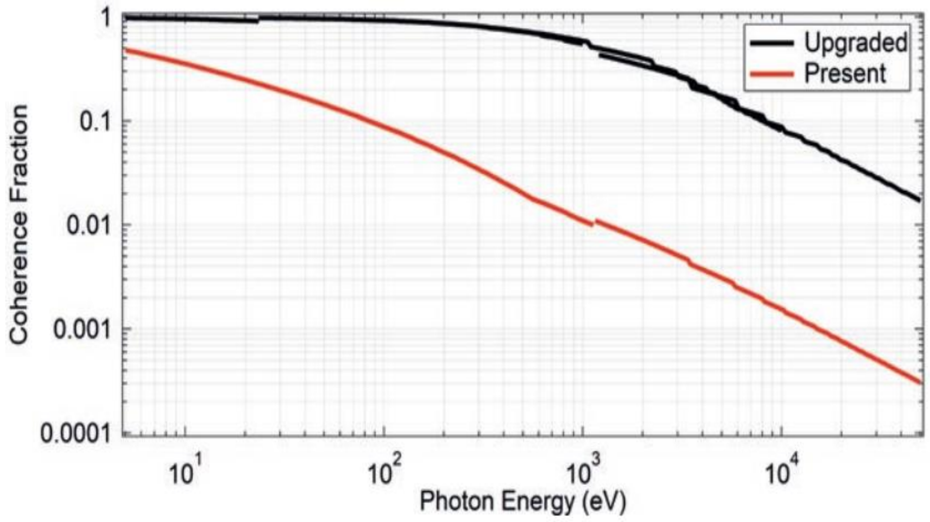
*Evolution of the **Spectral Brilliance** with the SOLEIL upgrade*



- IVUs shall be closed down to 4.5 mm full gap (instead of 5.5 mm of the majority today)
- Brilliance is increased thanks to the much lower beam emittance & to increased numbers of ID period
- There shall also be (six) 3T superbends and a N-pole wiggler foreseen to be installed in SOLEIL II



*Evolution of the **Photon Flux** with the SOLEIL upgrade*



*Evolution of the **ID coherent fraction** with the SOLEIL upgrade*

2.3 Targeted light source performance and foreseen IDs (2/2)

Table: Planar undulator sources

Straight section	BL	Category	E range (SOLEIL)	E range (SOLEIL II)	Phase	ID	L(m)
SD03C	LUCIA	1	0.6-8 keV with CP	0.5 - 8.5 keV Planar	1	IVU24	2
					2	CPMUn22	2
SD04C	PSICHE	2	17-100 keV	15 -100 (150) keV	1	IVW50	2
					2	CPMU_Wn35-27	2
SD07M	PUMA	2	4-60 keV	4-60/4-30 keV	1	IVU20	2
					2	CPMU16X	2
SD08C	CRISTAL	2	5-30keV	6 – 50 keV	1	CPMU18 (IVU20)	2
					2	CPMUn15	2
SD09C	GALAXIES	2	2.3-12 keV	2 – 22 to 25 keV	1	IVU20 (NdFeB)	2
					2	CPMUn16	2
SD13C	PX_alpha	1	6-18 keV	6-19 keV	1	IVU20 (SmCo)	2
					2	CPMUn16	2
SD14C	SWING	2	5-16 keV	4 -25 keV	1	IVU20 (SmCo)	2
					2	CPMUn15	2
SDL16	NANOSCOPIUM	2	5-20 keV	5-25 keV	1	CPMU18	2
					2	CPMU18	2
	ANATOMIX	2	5-40 keV	4-100 keV	1	CPMU18	2
					2	CPMU18	2
SDC18	SIXS	2	5-20keV	5-35 keV	1	IVU20 (SmCo)	2
					2	CPMUn16	2

List of foreseen planar undulators

- A series of spectral quality test performed by reducing the gap of IVU20 of the CRISTAL beamline to 4.5 mm. Its impact of the machine optics has also been studied.
- During the winter shutdown of 2025, the IVU20 of the CRISTAL beamline has been replaced by a CPMU18 to study its spectral performance and impact on the electron beam

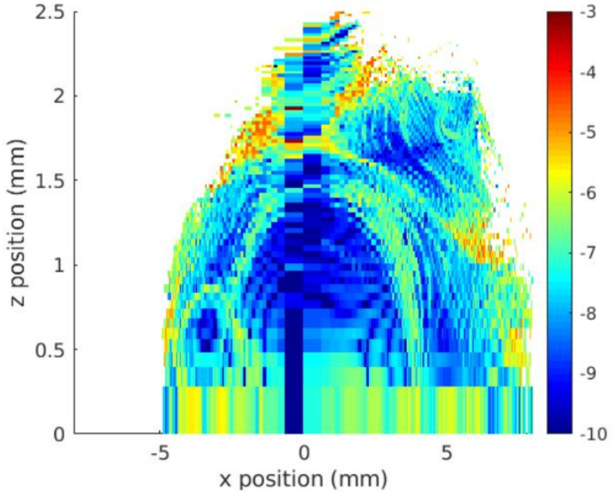
- APU250 (Adjustable Phase Undulator) is foreseen to be installed at the startup of SOLEIL II
- For the quality check purpose, a bi-periodic undulator prototype was designed, built and installed in the HERMES beamline. A series of beam-based experiments carried out to study its impact on the machine optics and compare measured spectral performance with simulations

List of foreseen Elliptically Polarizing Undulators

Table: EPUs

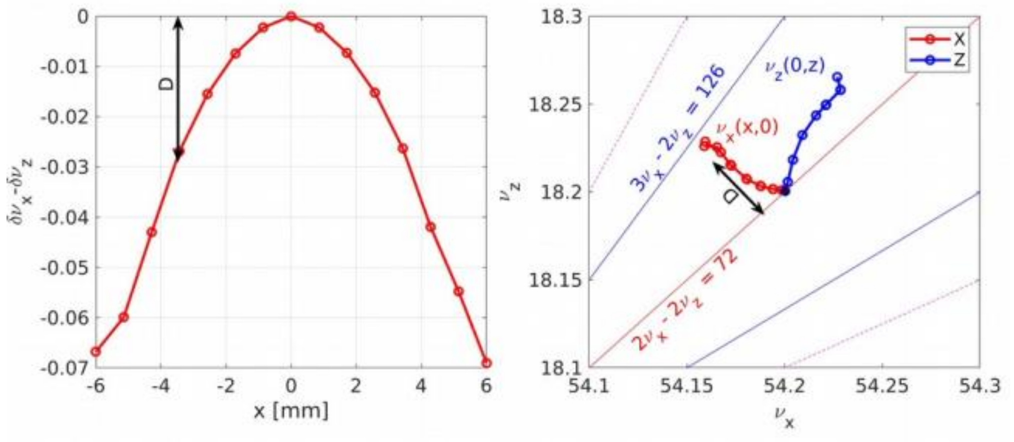
Straight section	BL	Category	E Range (SOLEIL)	E Range (SOLEIL II)	Phase	ID	L(m)
SD05M	PLEIADES	2	10-1000 eV	40 (20)-1500 eV	1	HU80/HU60	1.6
					2	AX63	2
SD06L	DEIMOS	1	350-2500 eV	200-2500 eV	1&2	Dual_HU52_EMPHU65	1.6
					Altern.	HU52 rapid speed	1.6
SD10M	TEMPO	2	50-1500 eV	50-2500 eV	1	HU80 (Dual HU80_HU44)	1.6
					2	DualN_HU40_HU70	2
SD11I	DESIRS	1	5-40 eV	5-40 eV	1&2	APU250	5
SD12M	HERMES	2	70-2500 eV	50-2500 eV	1	HU64	1.6
					2	BiP_HU44_HU88	2
SD15M	ANTARES	2	12-1000 eV	20-1000 eV	1	HU80 or HU60	1.6
					2	DualN_HU60_HU90	2
SD17M	SEXTANTS	2	50-1700 eV	H1:0.15-1.1 keV H3:1.1-1.8 keV	1	HU44	1.6
					2	AX46/IVUE40/CPMUE37	2
SD19C	SIRIUS	2	1.4-13 keV	0.5-13//2-30 keV	1	HU36	1.6
					2	AX38/IVUE33/CPMUE31 //CPMU16	2
SD20M	CASSIOPEE	1	8-1500 eV	10-1500 eV	1-2	HU80/HU60	1
						DualN_HU40-HU110	2

2.4 Beam dynamics challenges (1/5)

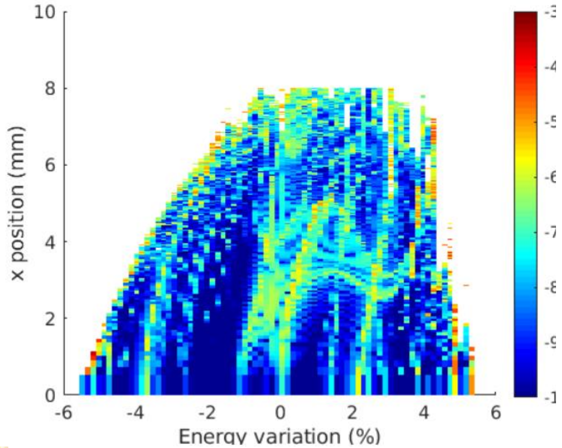


On-momentum DA at the injection point

- NL dynamics optimization of the symmetry one 7BA-4BA lattice:
  - Many active resonances around the WP
  - Strong sextupoles due to large natural chromaticities and small D_H
  - Optimization involving a huge number (~100) of nonlinear elements
  - $(\Delta p/p)_{local}$ > 4% to have $(\tau)_{Touschek}$ > ~3 hrs
  - Intensive MOGA optimizations on HPCs

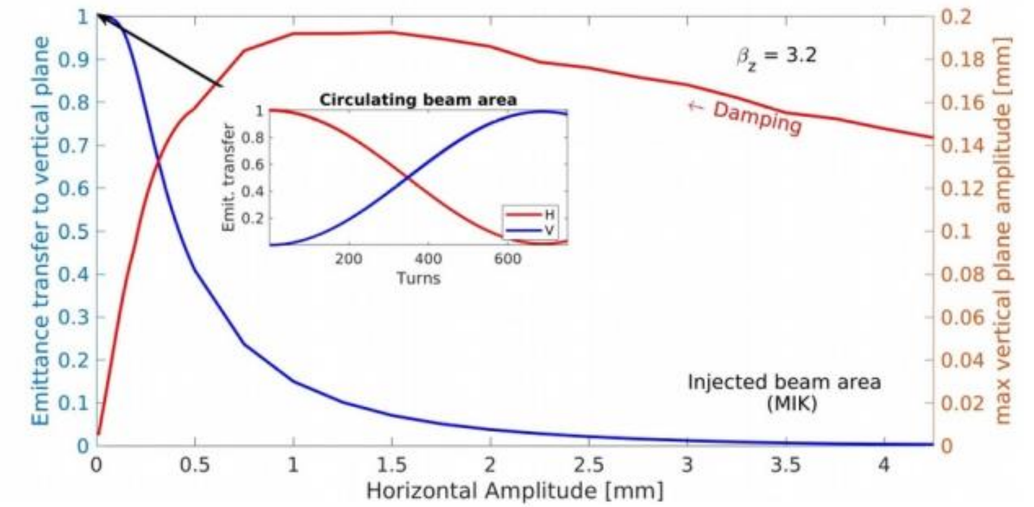


Left: Dissonance D = $\delta\nu_x - \delta\nu_z$ along the horizontal direction.
Right: On-momentum tune expansion



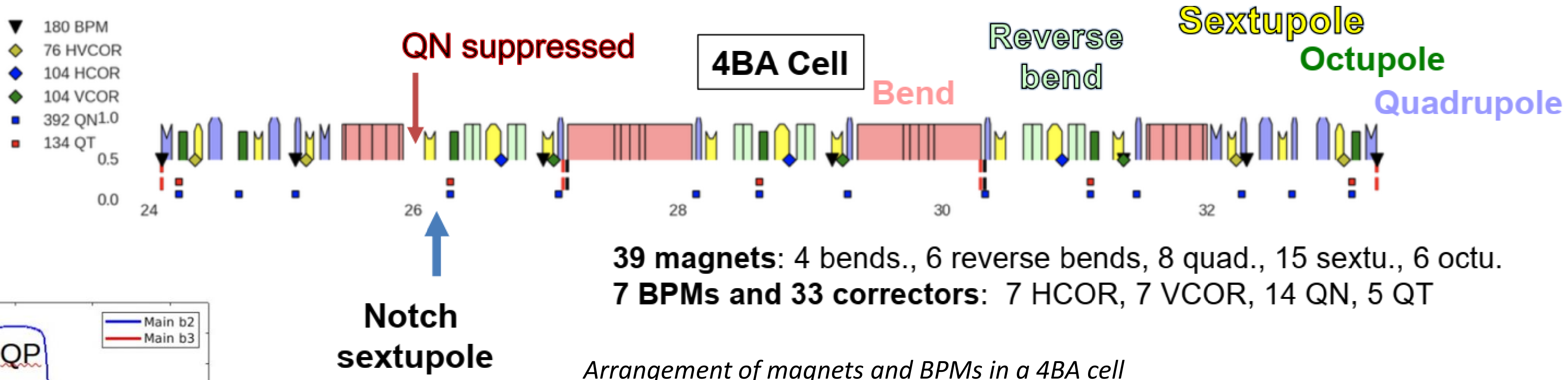
Off-momentum $(DA)_{Hor}$ at the injection point

- Attempt to operate the ring on a coupling resonance to generate a round beam:
  - Transverse emittance of ~50 pm.rad in both Hor/Ver planes may bring about significant benefits both for the machine and beamlines
  - A "dissonance" scheme optimizing the ADTS as a function of the horizontal amplitude is explored to enable off-axis injection



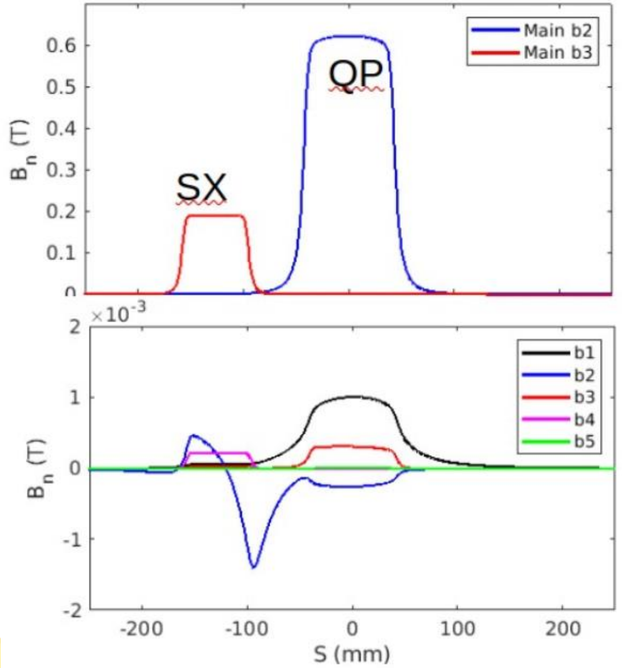
Coupling and vertical transfer vs $(amplitude)_{initial\ Hor\ amplitude}$ at injection center

2.4 Beam dynamics challenges (2/5)



39 magnets: 4 bends., 6 reverse bends, 8 quad., 15 sextu., 6 octu.
7 BPMs and 33 correctors: 7 HCOR, 7 VCOR, 14 QN, 5 QT

Arrangement of magnets and BPMs in a 4BA cell



Example of cross-talk multipoles (bottom) between a quadrupole and a sextupole (top)

- Extremely dense lattice with small vacuum apertures
- Use of permanent magnets for dipoles, quadrupoles and reverse-bends
- Introduction of thin electromagnets for sextupoles, octupoles with auxiliary coils for dipole and quadrupole (normal and skew) correctors
- Need to iterate the optimization of the lattice arrangement between machine physics, mechanical integration, magnet designs and vacuum system → Introduction special magnets with notches
- High risks of both static and dynamic crosstalks of the magnets, magnet saturation and hysteresis

2.4 Beam dynamics challenges (3/5)

Simulations of beam losses have found that an efficient collimation of Touschek scattered particles cannot be done due to the combination of small horizontal dispersion and small physical aperture in the ring

Demonstration that Collimation is not necessary for SOLEIL II (injection, lifetime electron losses)

Radiation Safety Risk

Requirements
- Public dose below **0.5 µSv/h** outside the tunnels with the **present wall thickness**
- Loss profile distributed over the ring
- Loss profile independent of the machine configuration (errors, IDs…)

Computations
- FLUKA simulations
- Loss profiles

Possible Mitigation
- Local reinforced shielding
- Special case (collimators…)

Demagnetization Risk

Permanent Magnets in the Arcs

Requirements
- Choice of Sm_2Co_{17} for dipoles, quadrupoles, reversed bends
- Neutron fluence below **10^{14} n/cm^2** over **25 years**

Computations & Experiments
- FLUKA simulations
- Magnet irradiation (CHARM)

Permanent Magnets for Undulators (IVUs)

Requirements
- Neutron fluence below **10^{12} n/cm^2 over 15-20 years** for NdFeB PMs

Computations & Experiments
- FLUKA simulations
- Magnet irradiation (CHARM)

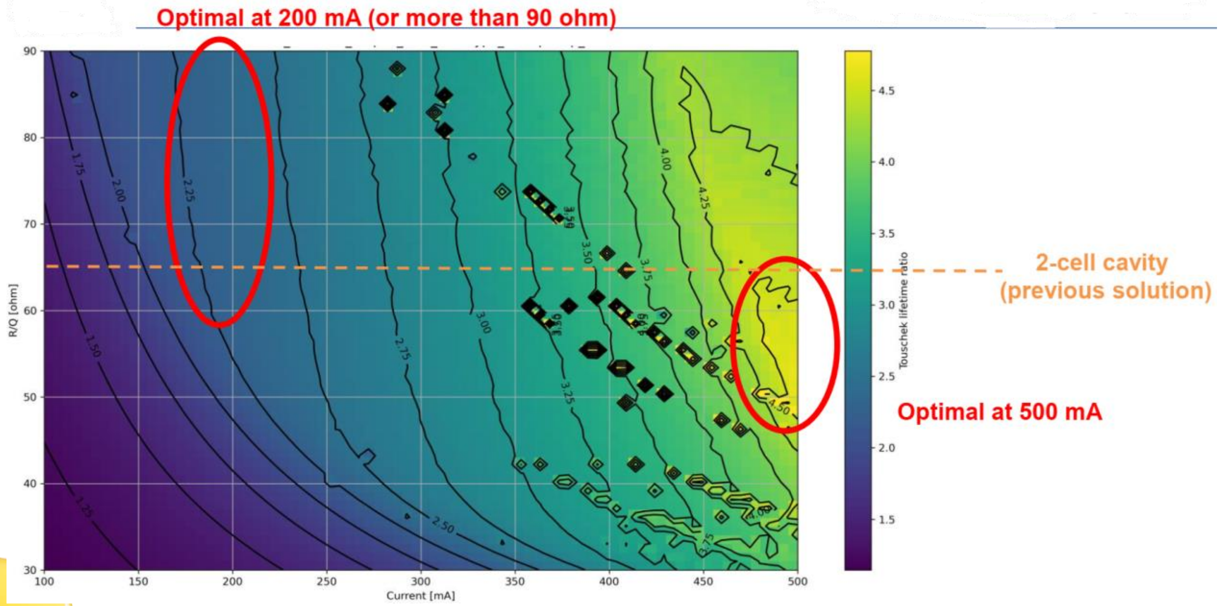
Special Collimators only for Beam Dumps

- Localization of most losses in the injection straight sections (special shielding)
- Dedicated kicker killers & decoherence kicker

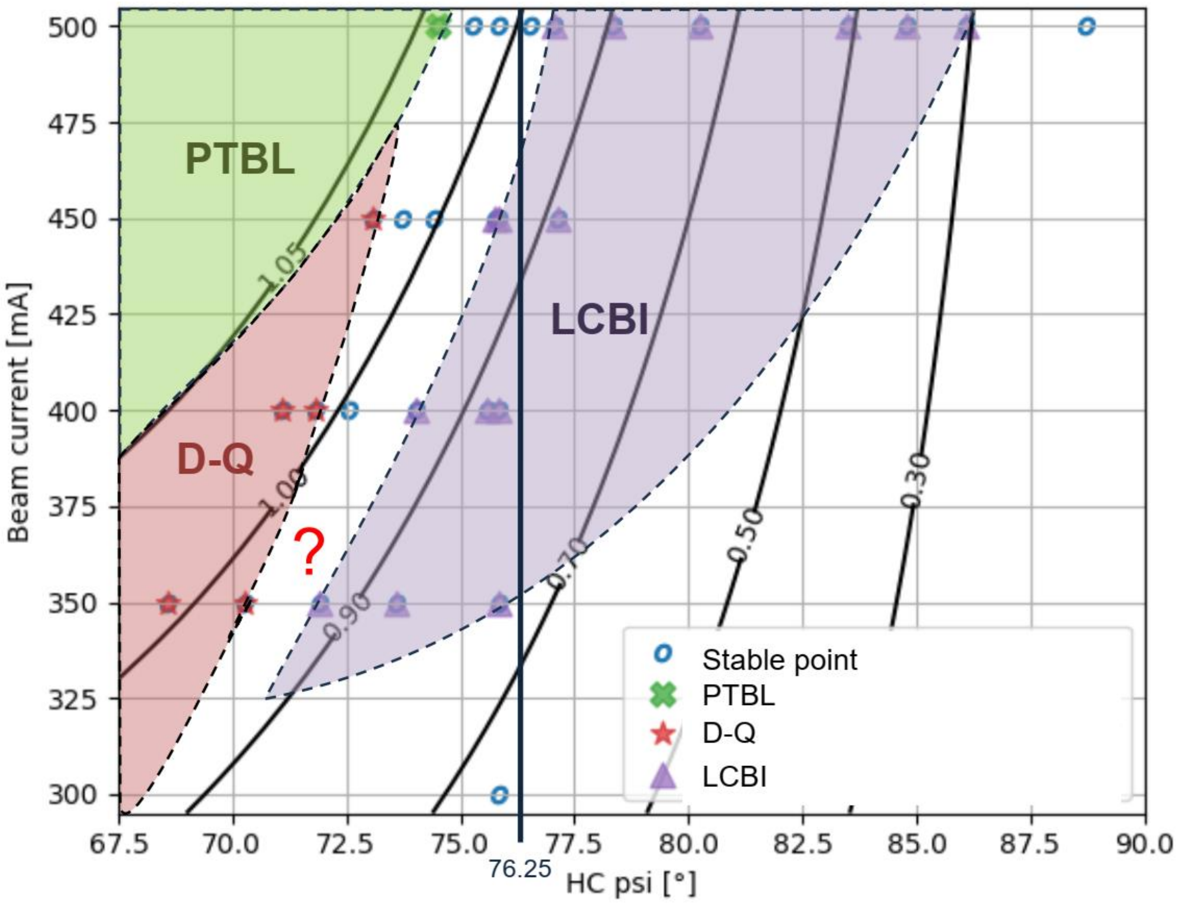
2.4 Beam dynamics challenges (4/5)

- For SOLEIL II operation with the designated ultra-low (natural) emittance of 85 pm.rad, it is ***vital*** to lengthen the bunch by factors larger than 3 to fight against Touschek and Intra-Beam Scatterings.

  → A series of numerical (multibunch tracking) and semi-analytical studies made to validate the MC-HC systems considered & developed that would keep the beam stable against AC-Robinson and HOM-induced instabilities



Search for optimal R/Q of HCs versus Ib [mA] to get maximal bunch lengthening



Multiparticle tracking (mbtrack2) with direct RF feedback on a RF system composed of 4×MC and 2×HC (NC passive).

PTBL (Periodic Transient Beam Loading instability)
D-Q (Dipole-Quadrupole modes instability)
LCBI (MC HOM-induced Longitudinal Coupled-Bunch Instability)

2.4 Beam dynamics challenges (5/5)

arXiv > physics > arXiv:2409.08637

Physics > Accelerator Physics

[Submitted on 13 Sep 2024]

Space Charge and Future Light Sources

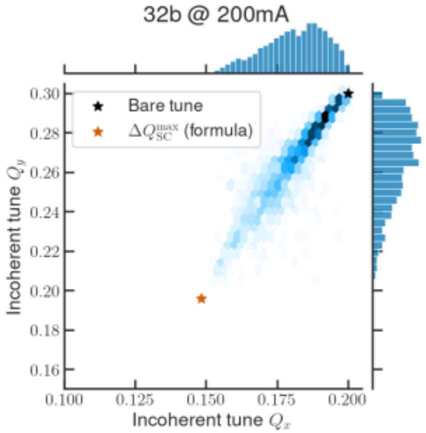
S. A. Antipov, V. Gubaidulin, I. Agapov, E. C. Cortes Garcia, A. Gamelin

It is a truth universally acknowledged, that space charge effects in ultrarelativistic elec
sources are approaching the point where their emittance becomes so small that the s
stability on the example of 4th generation light sources PETRA IV and SOLEIL II.

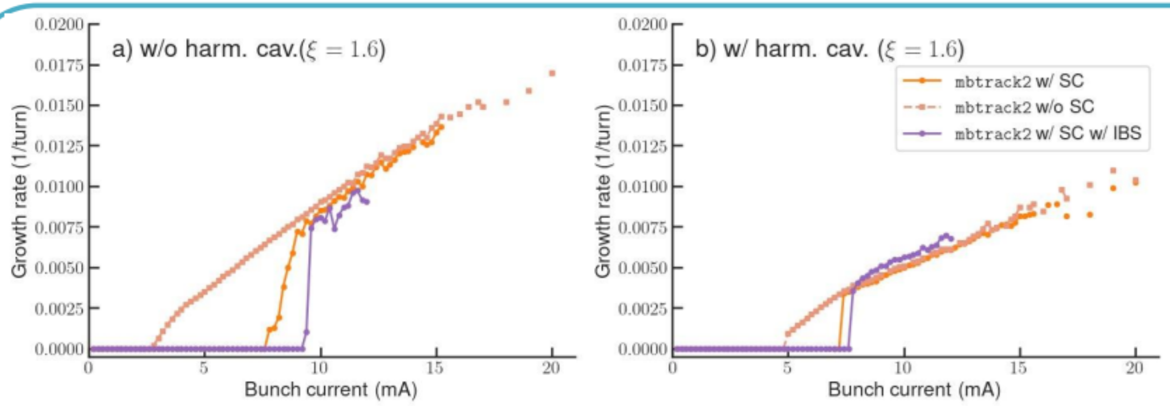
Submitted to Physical Review Accelerators and Beams
https://arxiv.org/abs/2409.08637

Large space-charge tune shifts in 4th-generation storage rings

$$\Delta\nu^{SC}_{x,y} = -\frac{N r_e C}{(2\pi)^{3/2}\gamma^3\sigma_z}\left\langle\frac{\beta_{x,y}}{\sigma_{x,y}(\sigma_x+\sigma_y)}\right\rangle$$



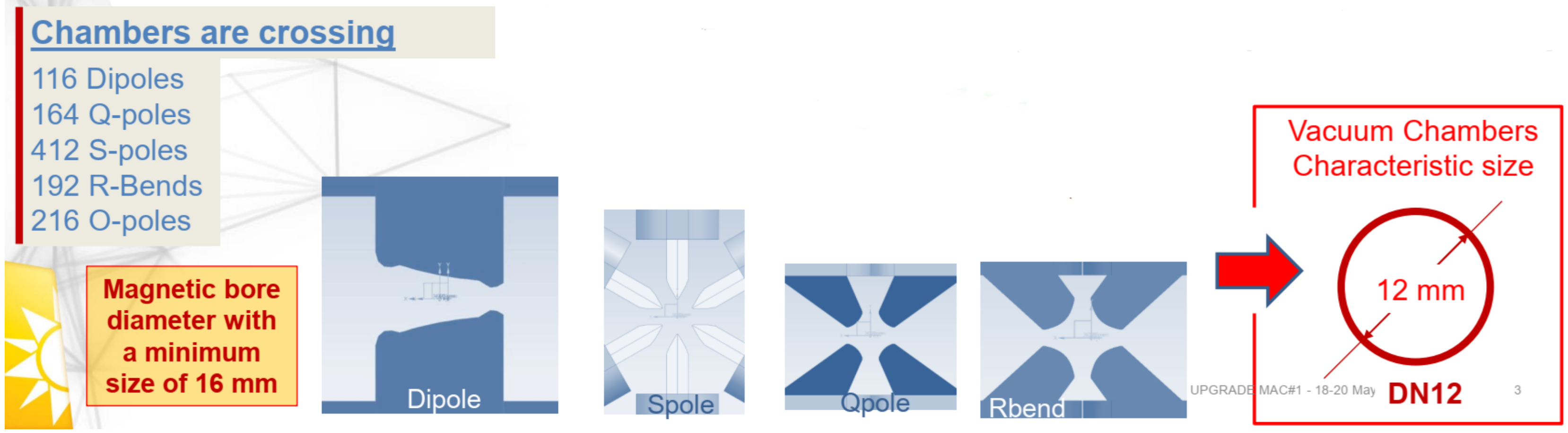
	SOLEIL@20mA/b	SOLEIL II(416b/32b)
Hor. Emittance (pm)	3900	84
Ver. Emittance (pm)	39	25
Bunch length rms (ps)	50 (assumed)	14 /25
Hor. SC tune shift	0.001	-0.006 / -0.017
Vert. SC tune shift	0.006	-0.013 / -0.038

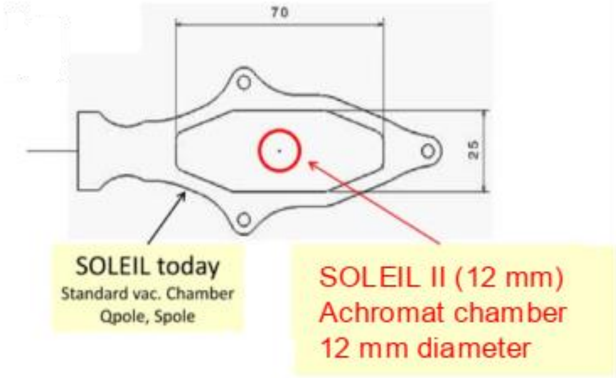


More than twofold increase of instability threshold currents!

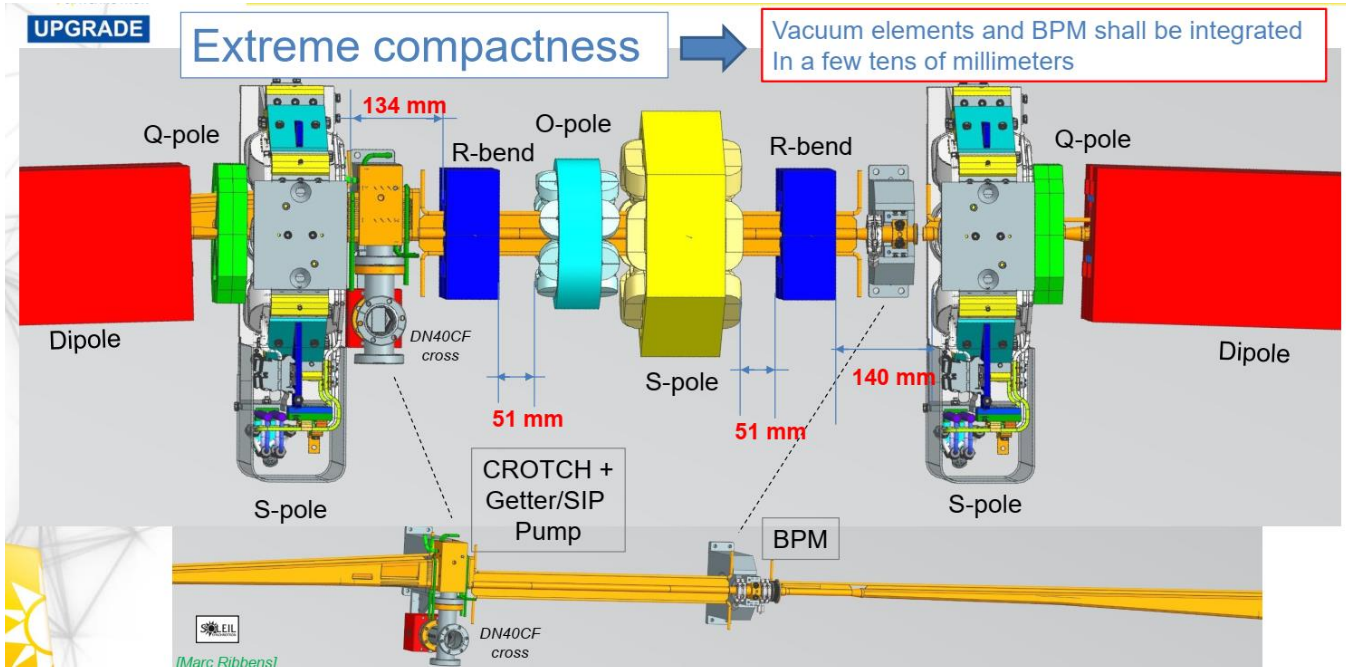
	w/o HC	w/ HC
w/o SC	2.8 mA	4.8 mA
w/ SC	7.6 mA	7.2 mA
w/ SC w/ IBS	9.4 mA	7.8 mA

2.5 Engineering and technological challenges (1/4)



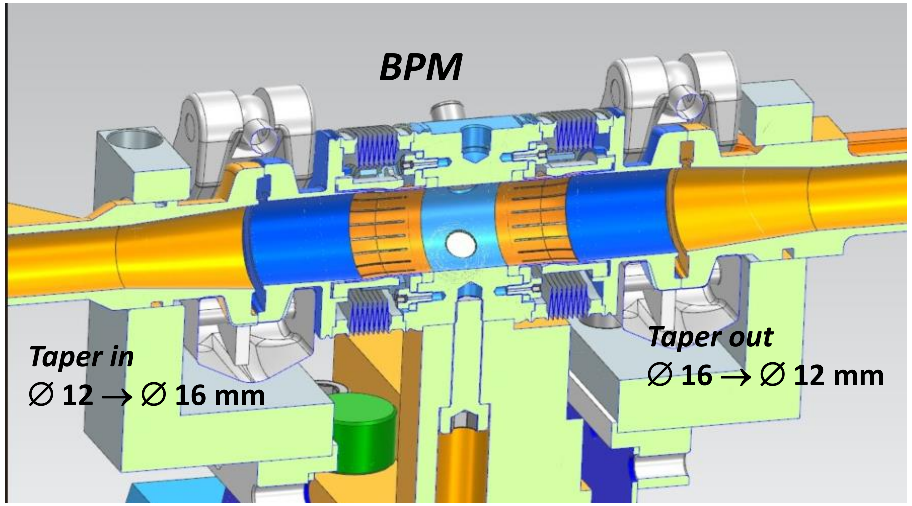


1-cent coin:
Its diameter is even wider 16.25 mm



- Due primarily to the need of using very high field for quadrupoles, sextupoles and octupoles for the SOLEIL II lattice, **the vacuum chamber diameter for the arc sections was set to be as small as 12 mm**.
- The 7BA-4BA HOA lattice adopted for SOLEIL II requires magnets and BPMs to be integrated with spacing down to merely some tens of millimeters.

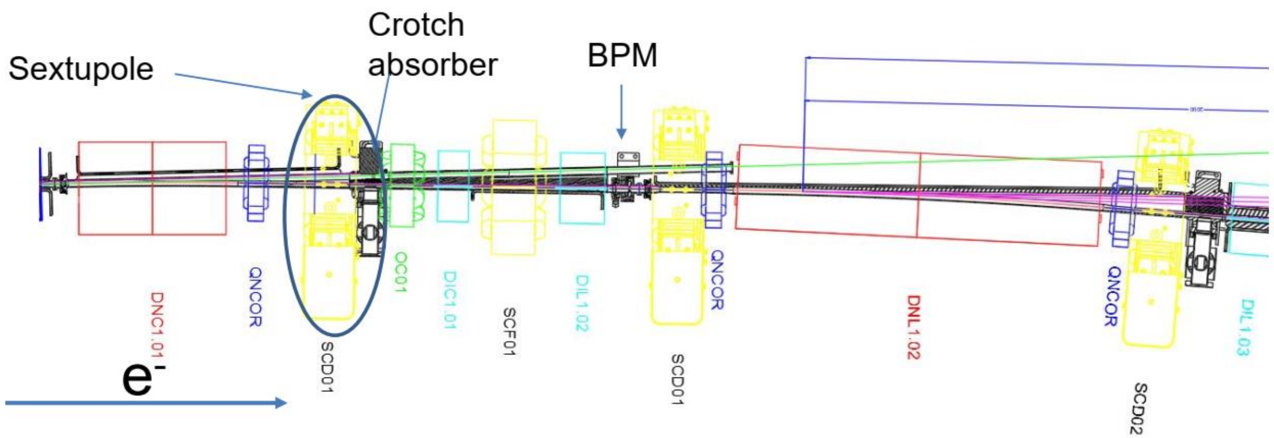
2.5 Engineering and technological challenges (2/4)



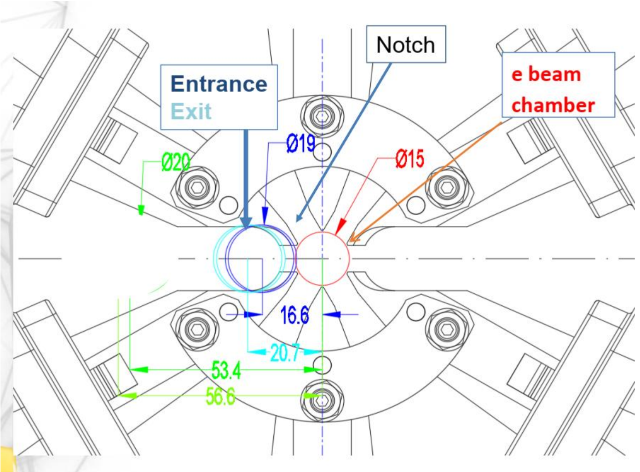
Tapers introduced on both sides of a BPM to protect its electrodes from synchrotron radiation (K. Tavakoli et al.)

- One critical issue that emerges due to the very small vacuum chamber aperture and the extreme compactness required for SOLEIL II is to guarantee the compatibility of;
  - Sustainability against radiation-induced heat load
  - Photon beam extraction for beamlines

with
  - Developed magnet lattice configuration
  - Beam lifetime, beam stay clear, collimation, machine interlock, …



Ray tracing of ID radiation to a downstream magnetic arc section (C. Herbeaux et al.)



Evaluation of a notch to introduce on an octupole due to upstream synchrotron radiation hitting its yoke (C. Herbeaux et al.)

2.5 Engineering and technological challenges (3/4)

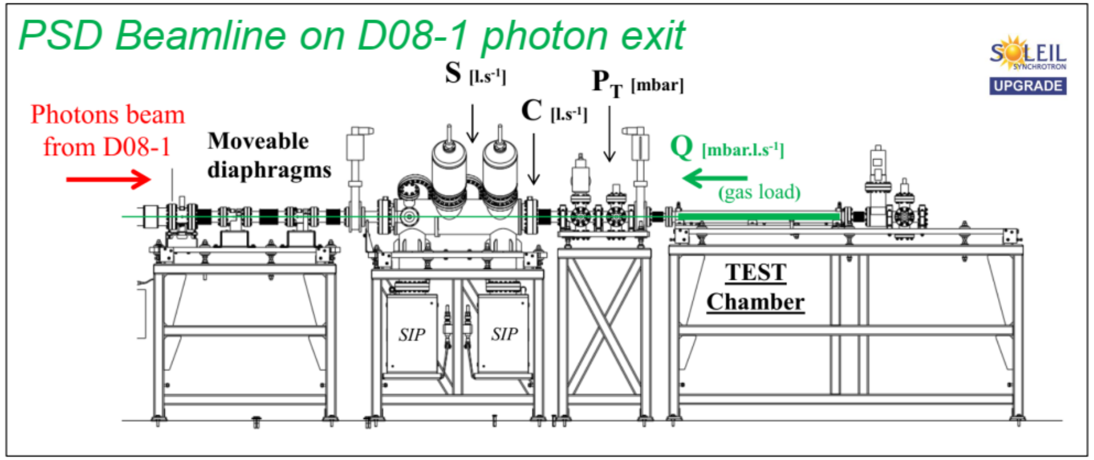
Vacuum pumping strategy adopted for SOLEIL II, which is composed only of small aperture vacuum chambers, and the aimed target: (*by Vincent Le Roux et al.*)

◊ Pumping scheme: Fully NEG coated (0.5 – 1 μm) chambers + one standard pump after each dipole

◊ Target: Less than 10^{-9} mbar @ 500 mA for Integrated dose of 100 A.h

◊ Strategy adopted to this end:

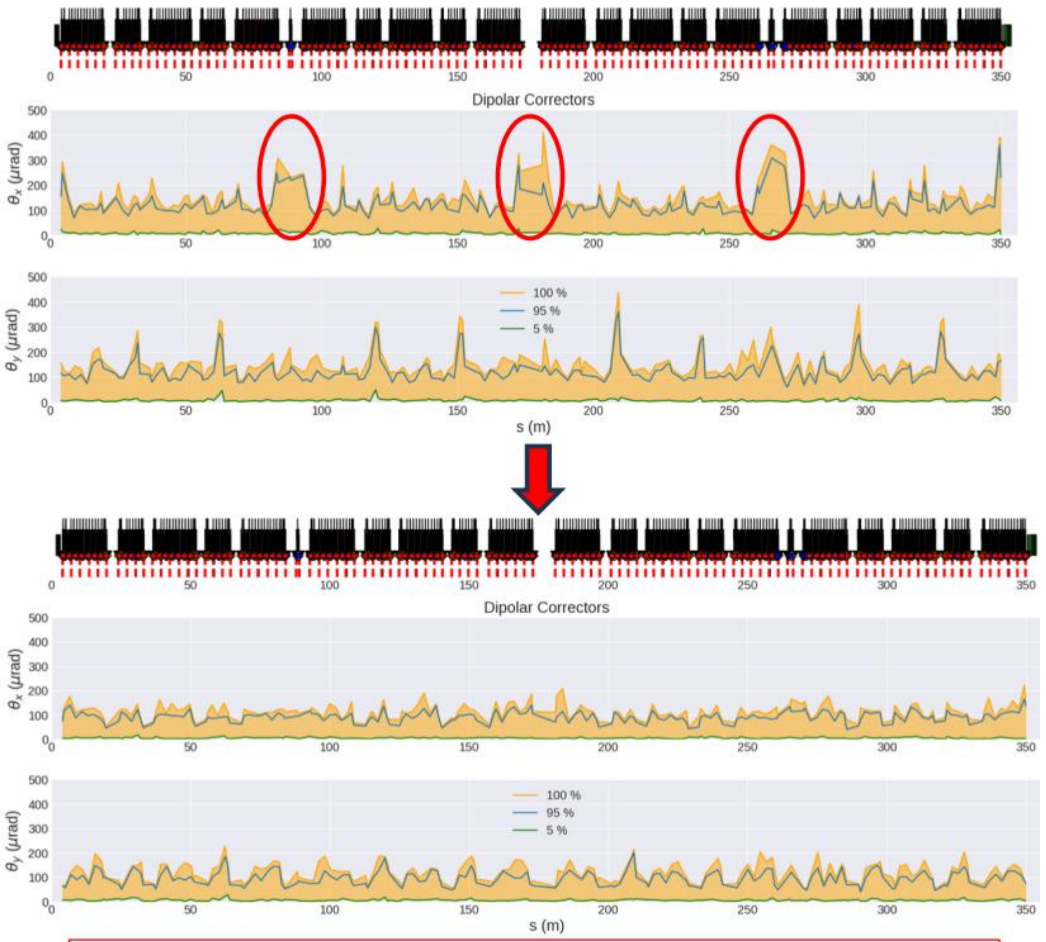
- NEG coating characterization at SOLEIL → Development of;
  - Test benches for two transmission factors : sticking factor and sorption capacity
  - One PSD (Photon Stimulated Desorption) measurement beamline
- Collaboration with external labs/manufacturers possessing NEG coating expertise
- Mastering of key simulation software tools available (MOLFLOW+, SYNRAD+, VacuumCOST, ...)



2.5 Engineering and technological challenges (4/4)

- Reducing the number of PM (Permanent Magnet) families to fabricate:
  - Adopt the same HOA unit cell between 7BA and 4BA
  - Decompose a long dipole into three parts and adopt the same outer dipoles all dipoles and merely change the central dipoles → This idea has recently been discarded.
  - For a group of quads, adopt the same pole profiles and differentiate them by their yoke lengths
  - Furthermore, equate their yoke length and differentiate them by introducing magnetic shims at the entrance and exit of a quad.

- Reducing the magnet alignment errors on a girder to **10 μm** rms:
  - Due to strong quads in the matching sections, the correction of orbit requires dipole kicks that are too high for dipole correctors to compensate the kicks of misaligned quads
    - → It was decided to reduce the misalignment errors of the magnets on a girder in the matching sections from 25 to 10 μm rms
    - → This allowed reducing the corrector strengths from 350 μrad to 200 μrad rms
    - → Today, the alignment group is seeking the feasibility of 10 μm rms magnet alignment on a girder by using the laser trackers in combination with Keyence sensors for fiducialization (*S. Ducourtieux et al.)*



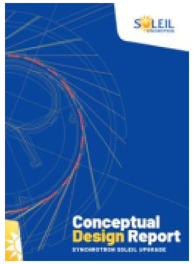
Correlated alignment in the matching sections

3. Major project timeline and milestones

3.1 Major project timeline and milestones

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035

CDR



TDR

- **Definition of deliverables**
- **Budget profile**
- **Machine specifications**
- Specs for Call For Tenders
- **Consolidated plan for infrastructure**
- **Experimental floor**
- Plan for beamline moves and restart
- **Project Management Organisation**

Shutdown

Stage 1: Construction

- Decommissioning of the current machine
- A new machine in operation
- Restart of all beamlines
  7-10 upgraded + 19 adapted BLs
- Upgrade of support laboratories
- R&D on enabling technologies

Stage 2: Towards full performances

- Full upgrade of the remaining 19 beamlines
- Upgraded support laboratories – Completion
- R&D programme on enabling technologies – Cont.

- Shutdown + commissioning: 24 months (restart of user program)
- Stage 1: 6 years
- SOLEIL II budget: ~ 309 M€ (inc. 15% contingency)
  → 252 M€ (Ministry-LPR) + (57 M€ from savings and members)
  - Stage 1 (6 years): ~ 186 M€ (42 M€)
  - Stage 2 (5 years): ~ 123 M€ (15 M€)

2025-2026: 50 M€ in line with our spending profile

Thank you for your attention

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