

SOLEIL Status and Upgrade Strategy for a DLSR

Laurent S. Nadolski
Accelerators Coordinator

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**

Location: France

Circumference: **354 m**

24 straight sections

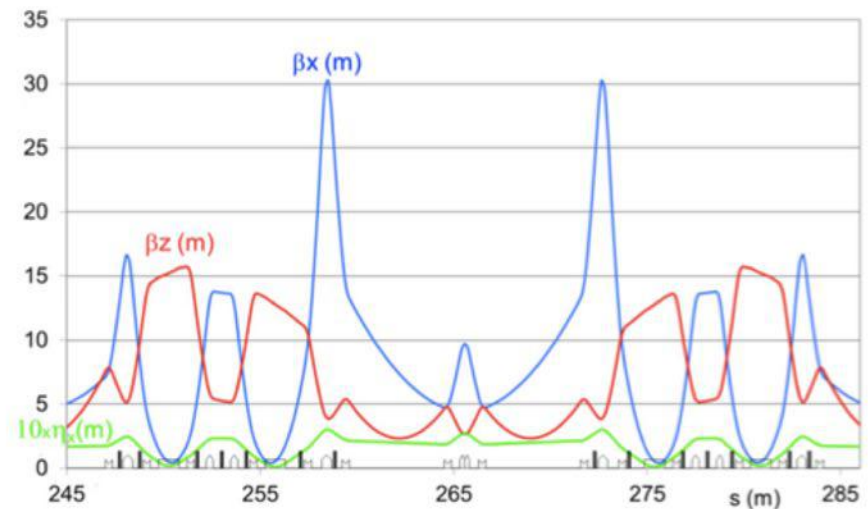
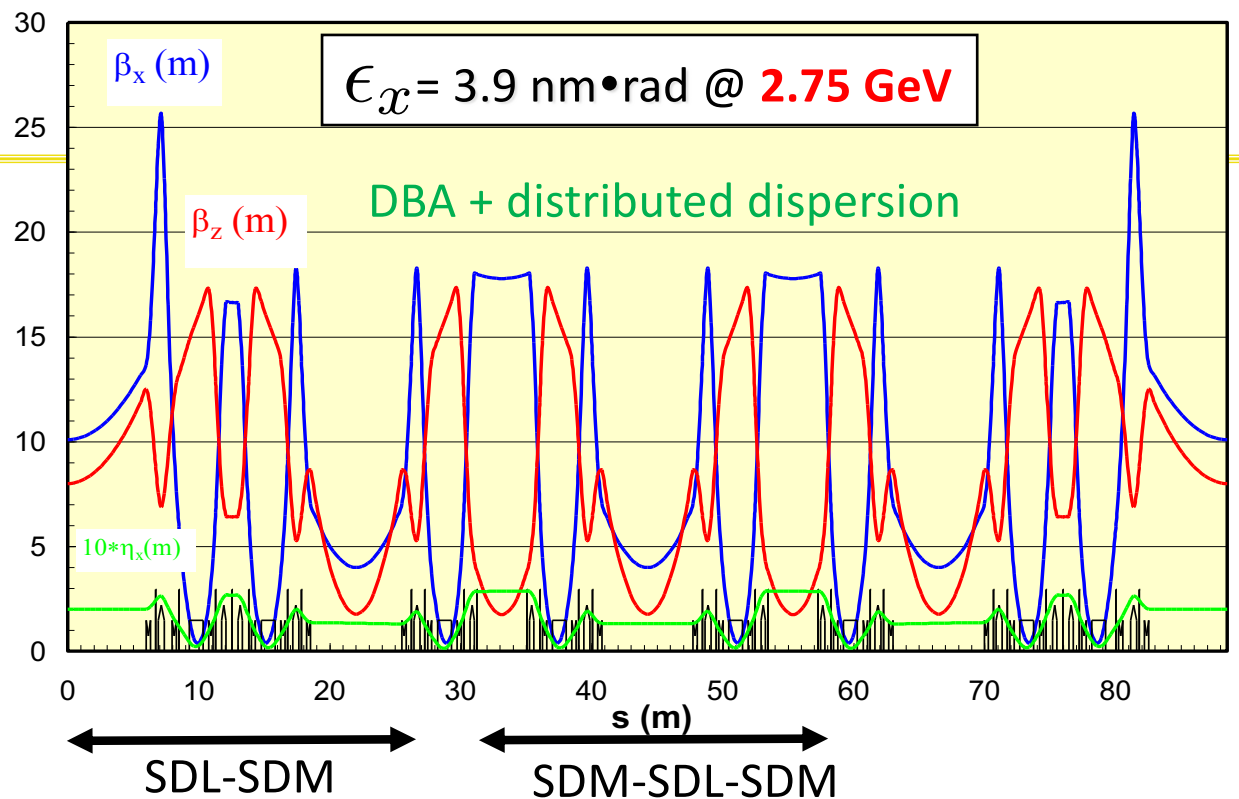
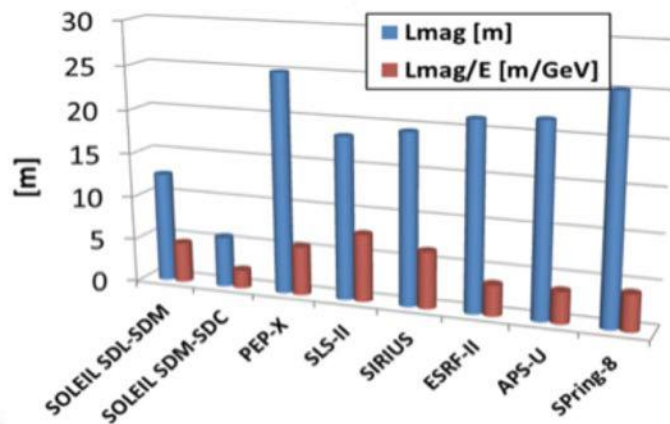
(variable length)

SDC: 4 x **12 m**

SDM: 12 x **7 m**

SDL: 8 x **3.6 m**

Very compact magnetic structure



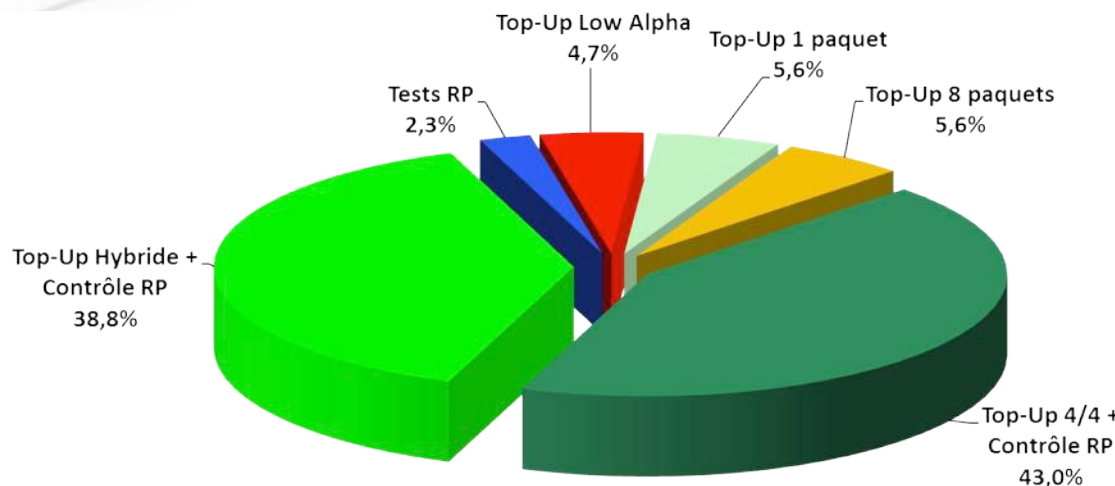
One long straight section (SDL13, accommodating 2 canted long beamlines) has **been modified**

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	jeu 01	dim 01	mar 01	ven 01	dim 01	mer 01	sam 01	lun 01	jeu 01	sam 01
mar 02	ven 02	ven 02	lun 02	mer 02	sam 02	lun 02	jeu 02	dim 02	mar 02	ven 02	dim 02
mer 03	sam 03	sam 03	mar 03	jeu 03	dim 03	mar 03	ven 03	lun 03	mer 03	sam 03	lun 03
jeu 04	dim 04	dim 04	mer 04	ven 04	lun 04	mer 04	sam 04	mar 04	jeu 04	dim 04	mar 04
ven 05	lun 05	lun 05	jeu 05	sam 05	mar 05	jeu 05	dim 05	mer 05	ven 05	lun 05	mer 05
sam 06	mar 06	mar 06	ven 06	dim 06	mer 06	ven 06	lun 06	jeu 06	sam 06	mar 06	jeu 06
dim 07	mer 07	mer 07	sam 07	lun 07	jeu 07	sam 07	mar 07	ven 07	dim 07	mer 07	ven 07
lun 08	jeu 08	jeu 08	dim 08	mar 08	ven 08	dim 08	mer 08	sam 08	lun 08	jeu 08	sam 08
mar 09	ven 09	ven 09	lun 09	mer 09	sam 09	lun 09	jeu 09	dim 09	mar 09	ven 09	dim 09
mer 10	sam 10	sam 10	mar 10	jeu 10	dim 10	mar 10	ven 10	lun 10	mer 10	sam 10	lun 10
jeu 11	dim 11	dim 11	mer 11	ven 11	lun 11	mer 11	sam 11	mar 11	jeu 11	dim 11	mar 11
ven 12	lun 12	lun 12	jeu 12	sam 12	mar 12	jeu 12	dim 12	mer 12	ven 12	lun 12	mer 12
sam 13	mar 13	mar 13	ven 13	dim 13	mer 13	ven 13	lun 13	jeu 13	sam 13	mar 13	jeu 13
dim 14	mer 14	mer 14	sam 14	lun 14	jeu 14	sam 14	mar 14	ven 14	dim 14	mer 14	ven 14
lun 15	jeu 15	jeu 15	dim 15	mar 15	ven 15	dim 15	mer 15	sam 15	lun 15	jeu 15	sam 15
mar 16	ven 16	ven 16	lun 16	mer 16	sam 16	lun 16	jeu 16	dim 16	mar 16	ven 16	dim 16
mer 17	sam 17	sam 17	mar 17	jeu 17	dim 17	mar 17	ven 17	lun 17	mer 17	sam 17	lun 17
jeu 18	dim 18	dim 18	mer 18	ven 18	lun 18	mer 18	sam 18	mar 18	jeu 18	dim 18	mar 18
ven 19	lun 19	lun 19	jeu 19	sam 19	mar 19	jeu 19	dim 19	mer 19	ven 19	lun 19	mer 19
sam 20	mar 20	mar 20	ven 20	dim 20	mer 20	ven 20	lun 20	jeu 20	sam 20	mar 20	jeu 20
dim 21	mer 21	mer 21	sam 21	lun 21	jeu 21	sam 21	mar 21	ven 21	dim 21	mer 21	ven 21
lun 22	jeu 22	jeu 22	dim 22	mar 22	ven 22	dim 22	mer 22	sam 22	lun 22	jeu 22	sam 22
mar 23	ven 23	ven 23	lun 23	mer 23	sam 23	lun 23	jeu 23	dim 23	mar 23	ven 23	dim 23
mer 24	sam 24	sam 24	mar 24	jeu 24	dim 24	mar 24	ven 24	lun 24	mer 24	sam 24	lun 24
jeu 25	dim 25	dim 25	mer 25	ven 25	lun 25	mer 25	sam 25	mar 25	jeu 25	dim 25	mar 25
ven 26	lun 26	lun 26	jeu 26	sam 26	mar 26	jeu 26	dim 26	mer 26	ven 26	lun 26	mer 26
sam 27	mar 27	mar 27	ven 27	dim 27	mer 27	ven 27	lun 27	jeu 27	sam 27	mar 27	jeu 27
dim 28	mer 28	mer 28	sam 28	lun 28	jeu 28	sam 28	mar 28	ven 28	dim 28	mer 28	ven 28
lun 29	jeu 29	jeu 29	dim 29	mar 29	ven 29	dim 29	mer 29	sam 29	lun 29	jeu 29	sam 29
mar 30	ven 30	ven 30	lun 30	mer 30	sam 30	lun 30	jeu 30	dim 30	mar 30	ven 30	dim 30
mer 31	sam 31	sam 31	jeu 31	dim 31	mer 31	dim 31	ven 31	lun 31	mer 31	dim 31	lun 31

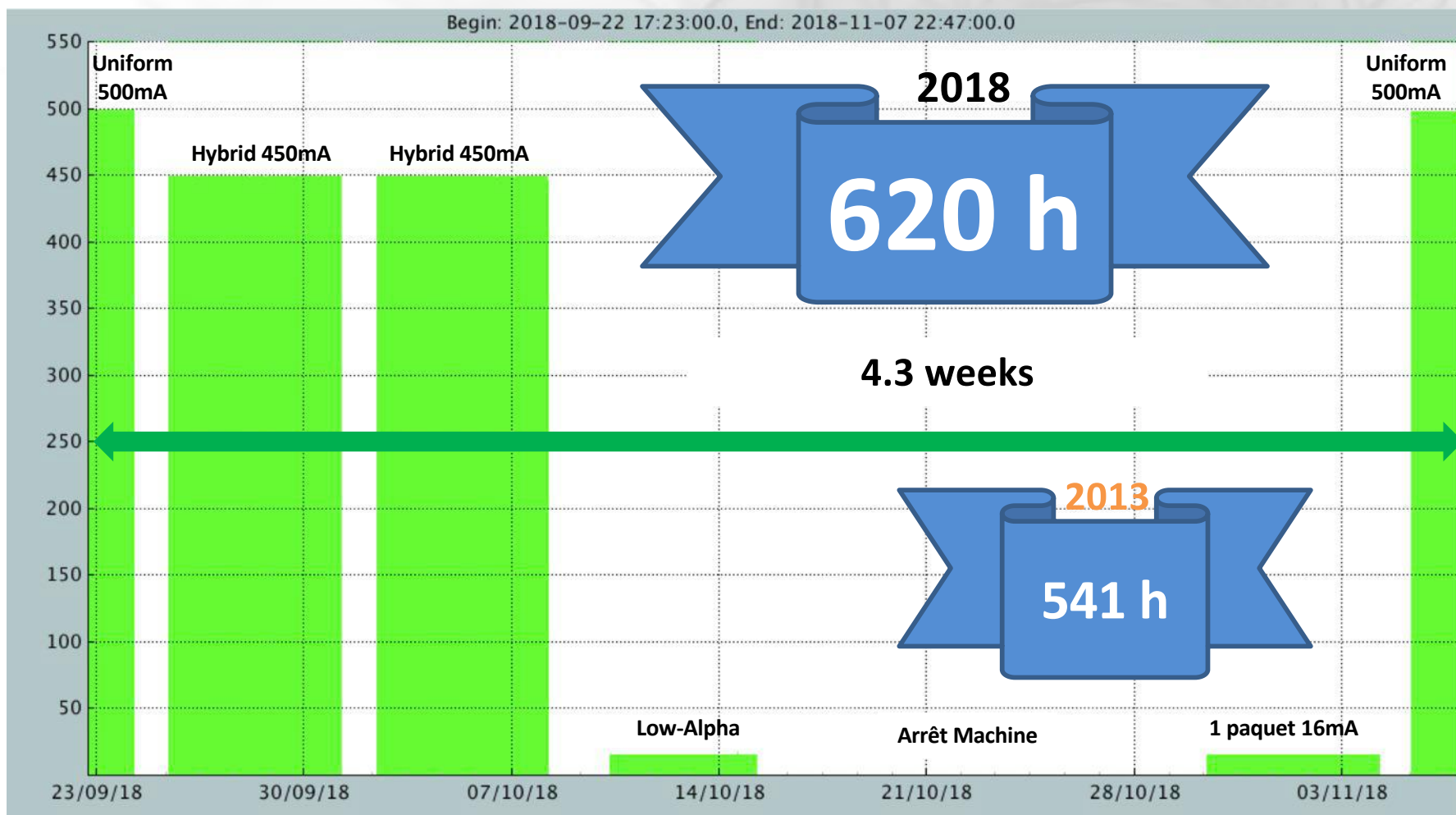
U	Uniform
H	Hybrid / camshaft
8	8 bunches
S	1 bunch
L	Low-Alpha
B	Beamlines
Cp	Periodic radiation safety checks
Tv	Radiation safety validation,
A	Accelerators
.	Shut down



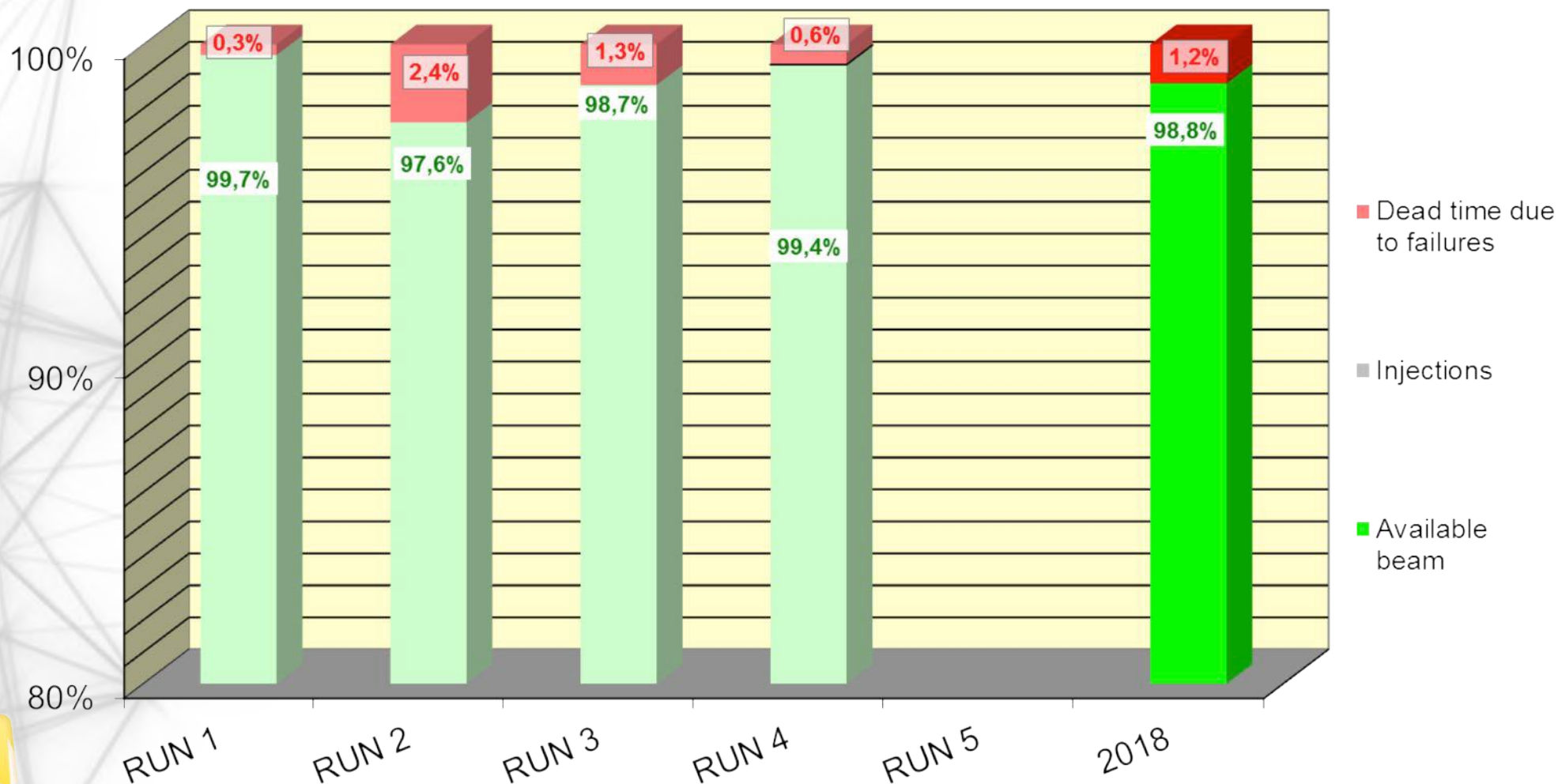
MTBF = **80 hours** and MTTR = **0h58**

Accumulated beam dose since commissioning > **20 000 A.h**

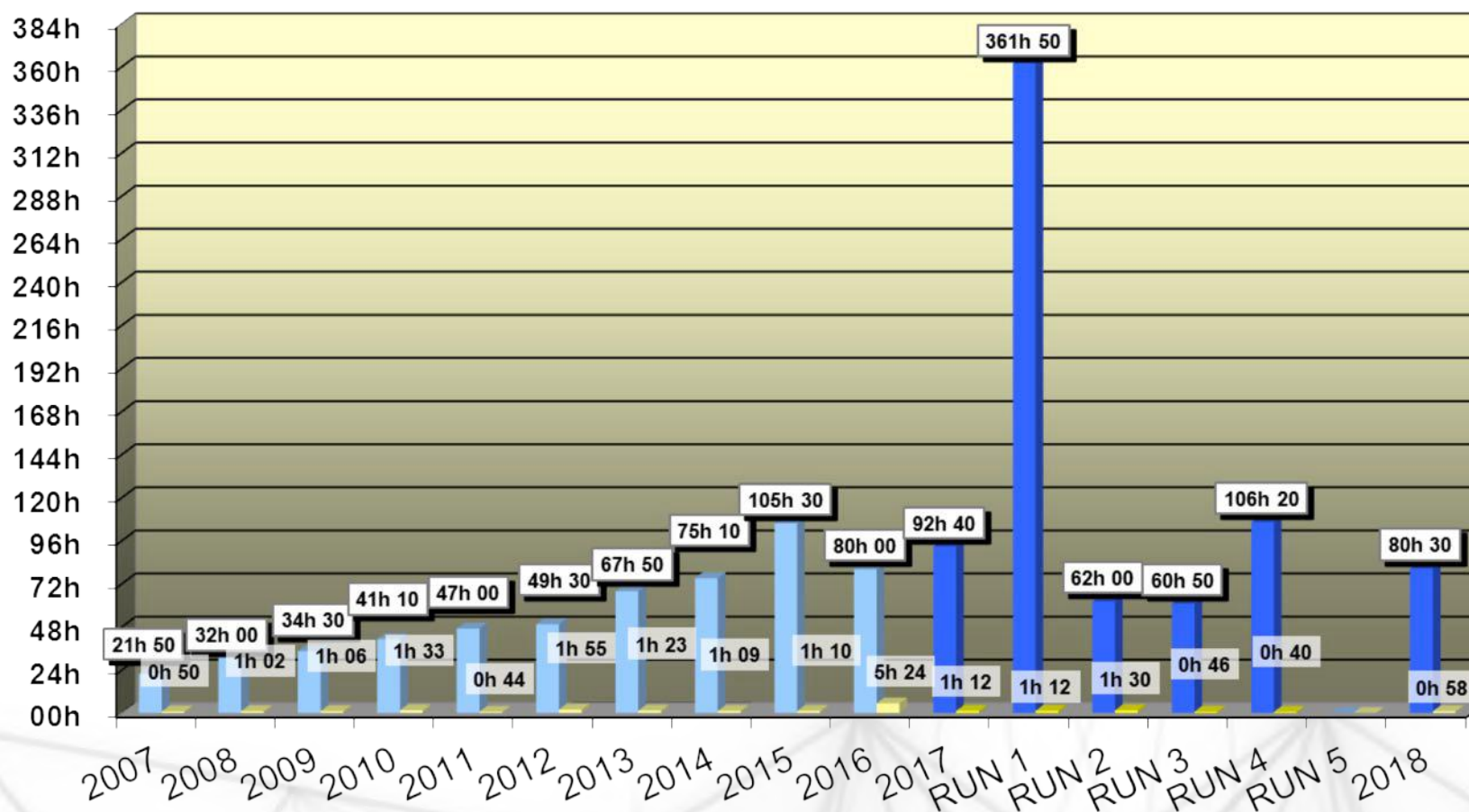
New Record for the longest uninterrupted beam for users



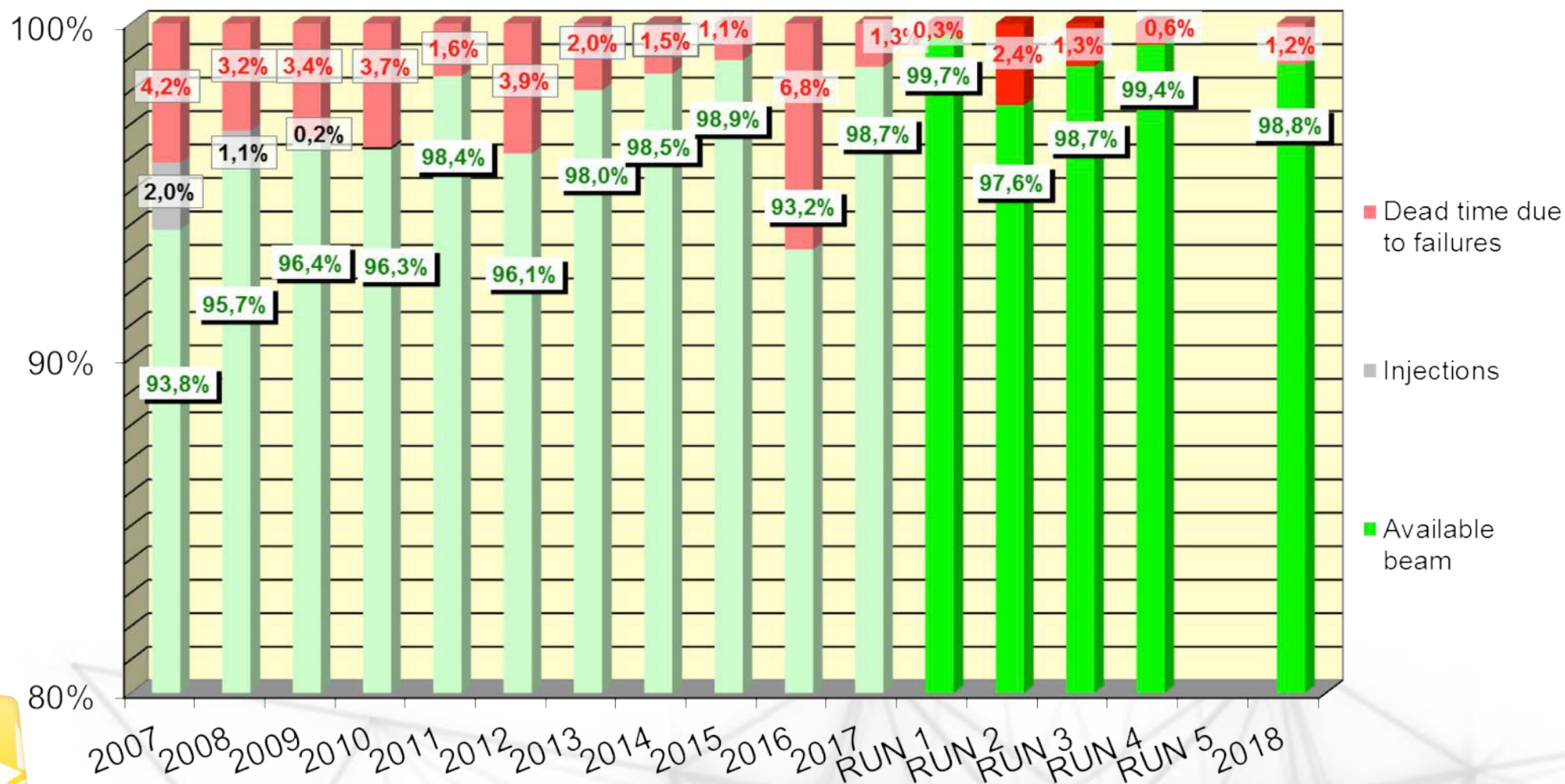
Photon Beam Availability (2018: Run1 to Run 4)



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



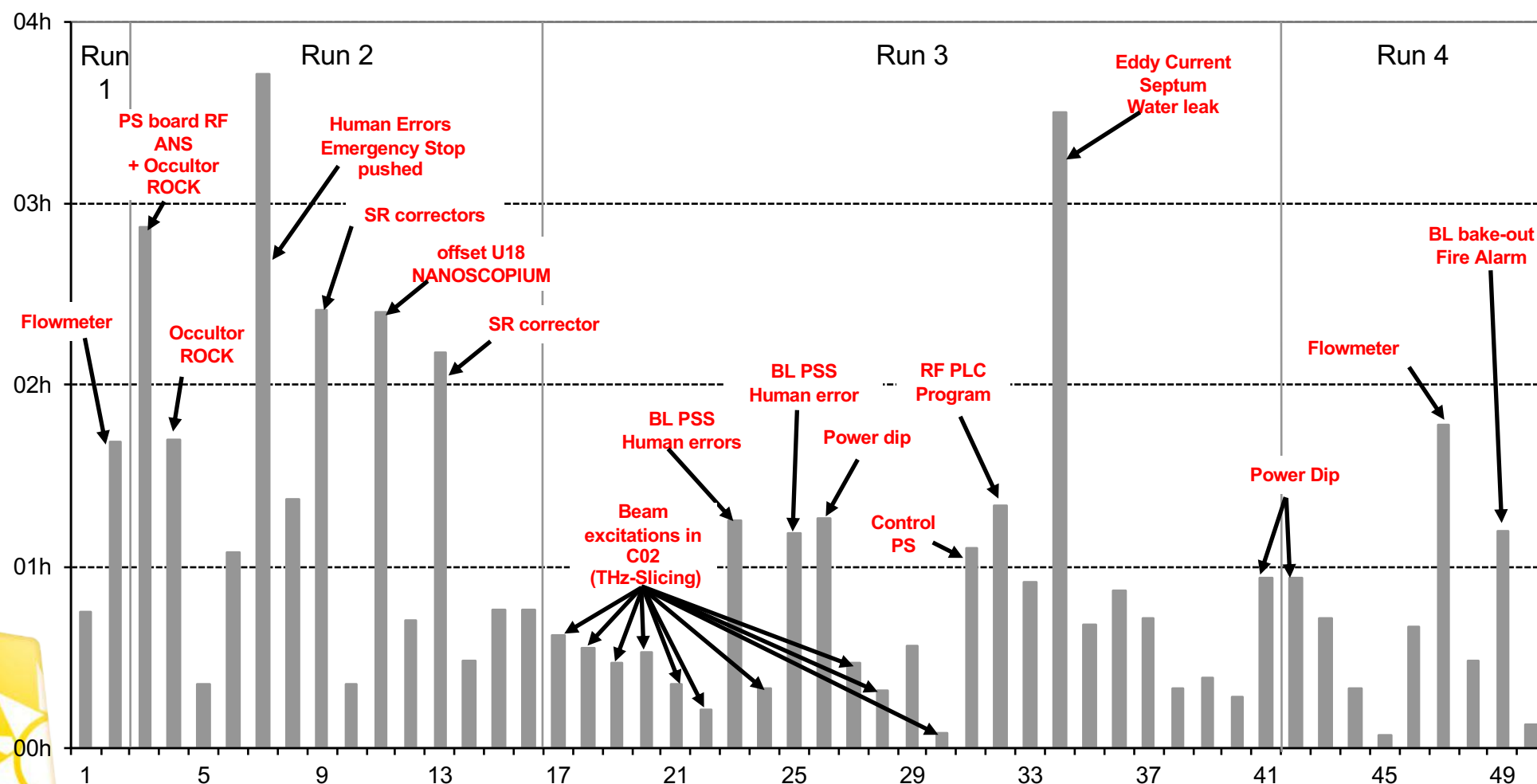
Efficiency during beamlines and RP sessions in 2018
4024 hours of beamtime delivered
 represent a beam availability of **98,8 %**



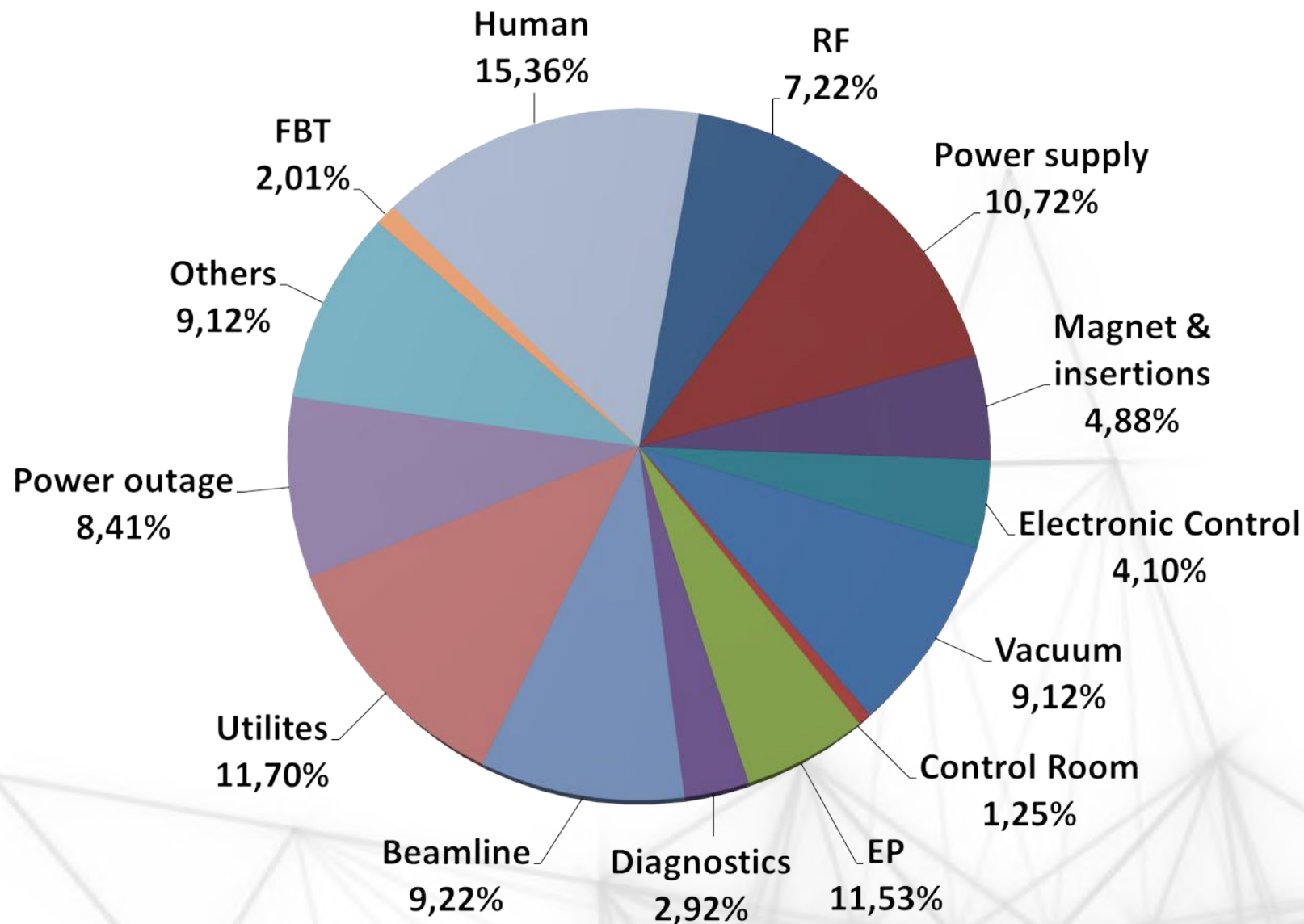
Duration of every interruption (Run 1 to 4)

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)



Migration from Elog to JIRA



SOLEIL SYNCHROTRON **LogBooks**

Synchrotron | Historique

Cahier Machine | Cahier de bord SDC | Operation | RP | Groupe GMI | Groupe Vide | RF | Groupe Diag&Synchro | linac

Groupe Fonctionnement Connecté sous "Opérateur"

Liste | Créer | Modifier | Répondre | Dupliquer | Chercher | Se déconnecter | Aide

Numéro de message: 4159 Heure de l'entrée: 02 July 2017, 03:41

Type de fiche:	Panne
Date evenement:	02 July 2017, 01:05
Auteur:	S. Garnier
Avec astreinte:	Oui
Criticite de la panne:	3
Incidence Faisceau:	Disponibilite faisceau
Groupe:	AE
Sous ensemble:	Anneau
Localisation:	C13
Equipement:	ANS-Cor.
Default:	OverCurrent
Date de fin:	02 July 2017, 03:41
new metrics:	No-beam
duree NM:	02h36m00

Symptome: Perte faisceau interlock position

Diagnostic: l'alim S4-CV en C13 est passé de 3 à 15 A.

Remède final "feu vert": L'astreinte AE a changé la carte de régulation puis PB sur S12 1 CV en C13 pendant un cyclage, la carte a dû aus

Les 2 cartes de régulations sont tombées en panne. Pour la 1^{ère} fois il s'agit de la référence courant qui est partie, la carte a donné une n à un problème de soudure sèche. Les 2 cartes ont été réparé, elles ont été remise le lundi 10 juillet

OASIS 06/07: 1^{ère} carte S4-CV : problème sur le DAC de la carte., 2^{ème} Carte S12.1 CV : problème de soudure sèche. => les 2 carte ont ét

01h05 : Perte faisceau
La perte est lente, on voit sur le PM BPM que la derive se fait sur plusieurs milliers de tours (attachement 8)
alim S4-CV en C13 en défaut overcurrent, en TDB on voit que la relecture est subitement passée de 3A à 15A !

Je joins l'astreinte qui me demande de descendre rebooter le tiroir.
Pas d'amélioration, elle se déplace.

J'ai trouve des pannes similaires sur les alims correcteurs, elles avaient necessite un changement de la carte de regulation.

2h15 : L'astreinte est sur place, début d'intervention

Yazid a changé la carte de régulation de la S4CV.

SOLEIL Tableaux de bord Projets Demandes Tableaux BigPicture Créer Recherche

Incidents en cours Interventions en cours Demandes service en cours Bon de Travaux Maintmedia Changements Informatiques pour le RUN4-2017 Aide JIRA

INF_ServiceDesk

HU80 en défaut

Modifier Commentaire Attribuer Suite Escalade to level 3 Resolve Ask For information Gérer Mail Exporter

Informations

Type:	Incident	Etat:	NIVEAU 2
Priorité:	2 - Modéré		(Afficher le flux de travaux)
Composants:	Operation Machine	Résolution:	Non résolu
Étiquettes:	Aucune		
Période intervention:	heures de travail		
Incidence Faisceau:	Ligne		
Groupe & Equipements:	GMI - HU80 - Changements encodeur		
Machine New metrics:	Beam-unrelated		
Localisation Machine:	ANS-C07		
Durée new metrics:	HH:MM:SS		
Durée d'incident:	0h		

Personnes

Responsable: NIADOLSKI Laurent
Me l'affecter

Rapporteur: MARION Thomas
Votes: 0
Gérer les observateurs: Arrêter l'observation de cette demande

Dates

Création: 12/sep/17 16:19
Mise à jour: 14/sep/17 10:45
Heure debut: 12/sep/17 16:22
Heure fin: 12/sep/17 16:23

Description

HU80 en défaut -> Changement encodeur nécessaire

Pièces jointes

Glissez-déposez des fichiers pour les joindre, ou parcourir:

Opérations disponibles

Rechercher un root cause Créer une intervention

Activité

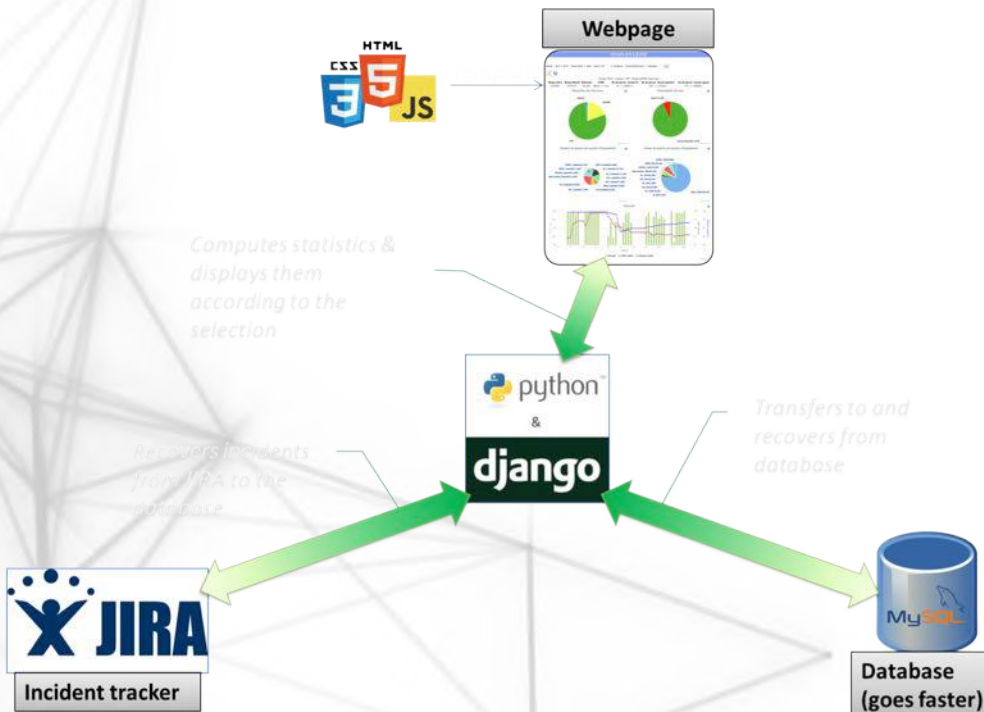
Toutes Commentaires Journal de travail Historique Activité Mails Transitions

MARION Thomas a ajouté un commentaire - 14/sep/17 10:45

Panne d'illustration présentation incident JIRA

Commentaire

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



Dernière actualisation des pannes : 12/10/2017 18:34

STATISTIQUES DES ACCELERATEURS

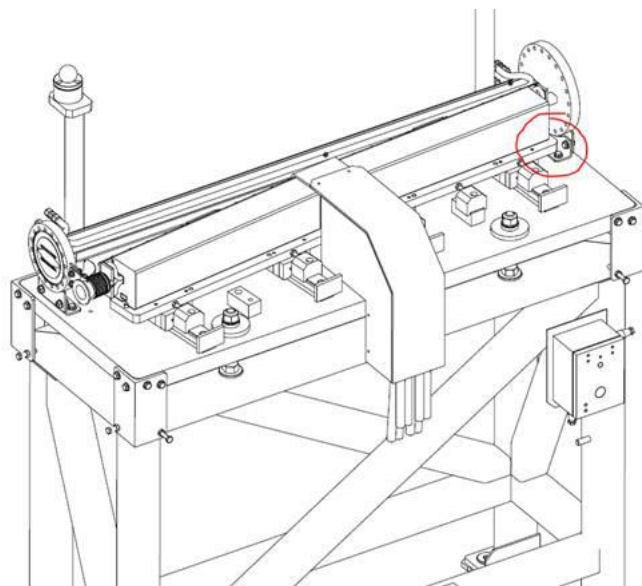


Status of SOLEIL and Upgrade Plan, XXVI ESLS, Krakov, 2018

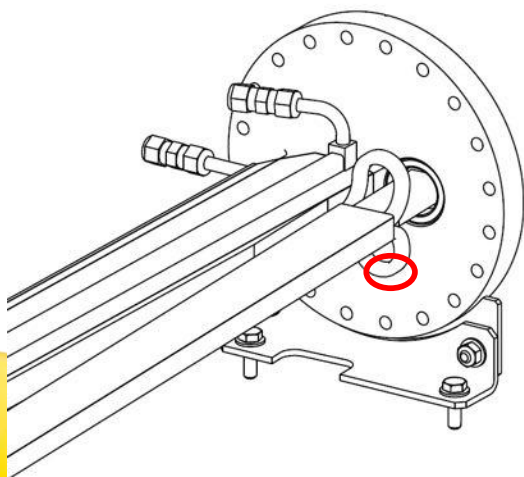
Elog	Type	Date debut	Date fin	Durée	Incidence	Groupe	Equipement	Texte
3443	Panne	2016/12/19	2016/12/19	0h11	Injection	LIUAC	PC salle Lignes	Alarme rendement LPH trop faible, rien ne sort du Lignes en attente un coup toujours rien sur le Lignes message "DataSocket/Server/Normal operation" mais rien en défaut je descend sur le PC en salle Lignes j'appelle l'ordinateur LPH et on relance les

SR Eddy Current Septum: **water leak**

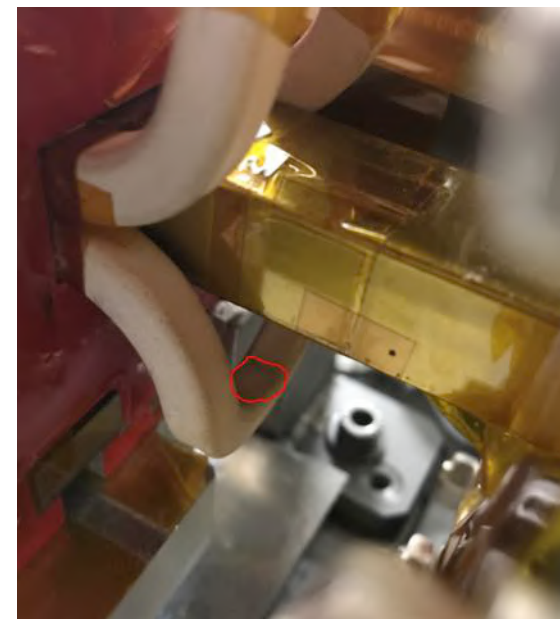
Detected on June 19th, 2018



Microcracks



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



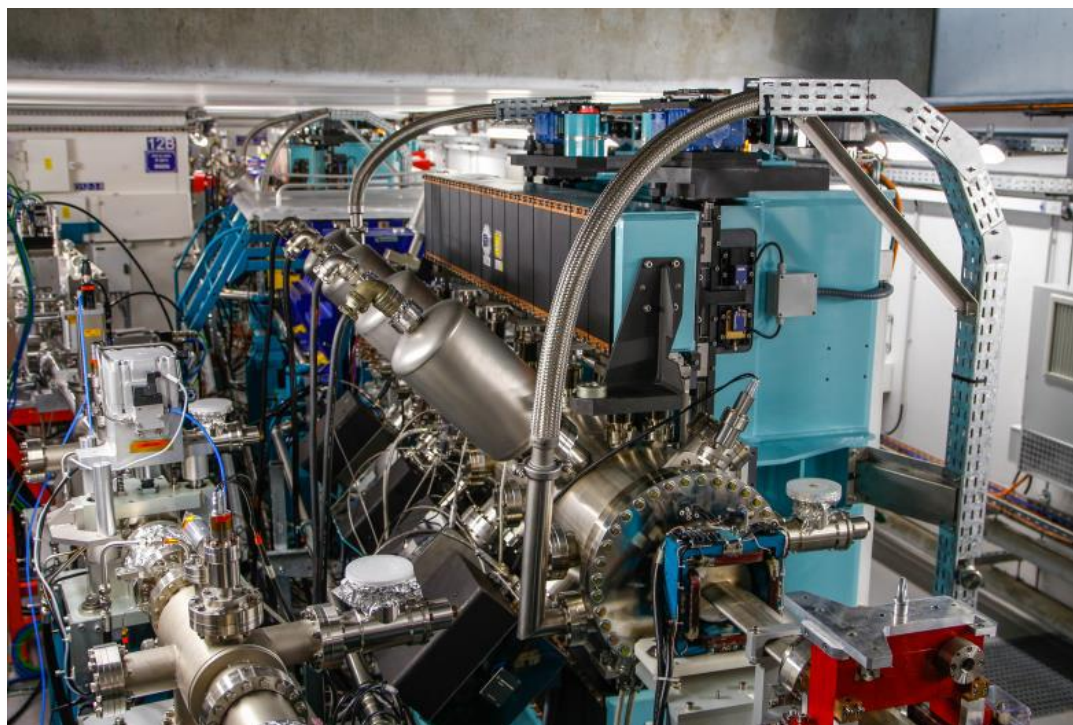
On-going Projects A Personal Selection



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.

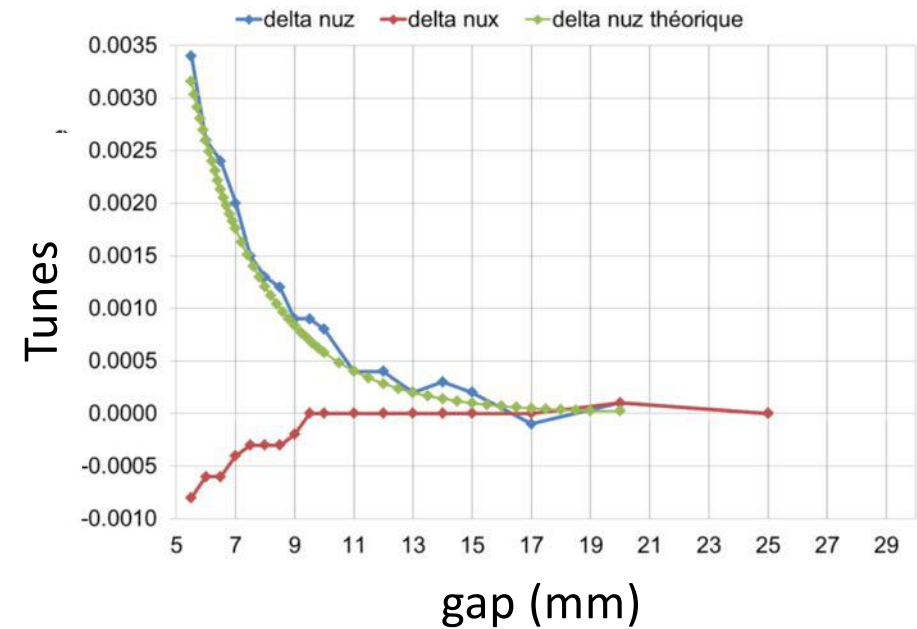
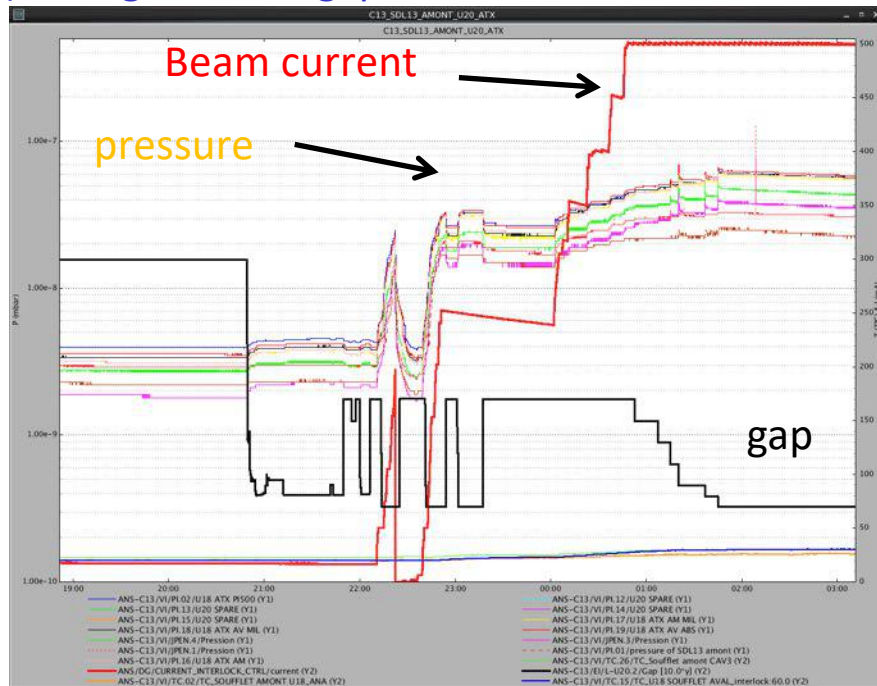
Canted SS with two 5.5 mm in-vac. CMPUs



CMPU: Commissioning of U18

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

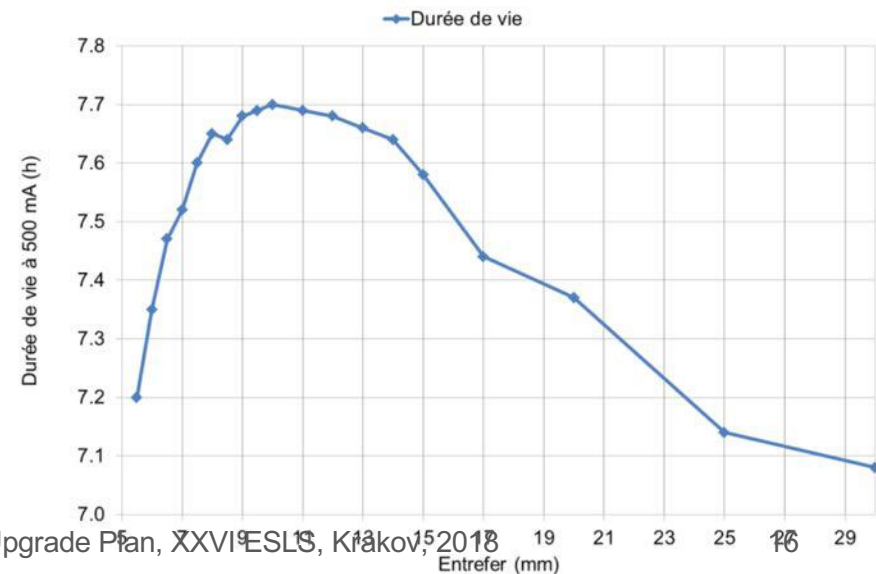
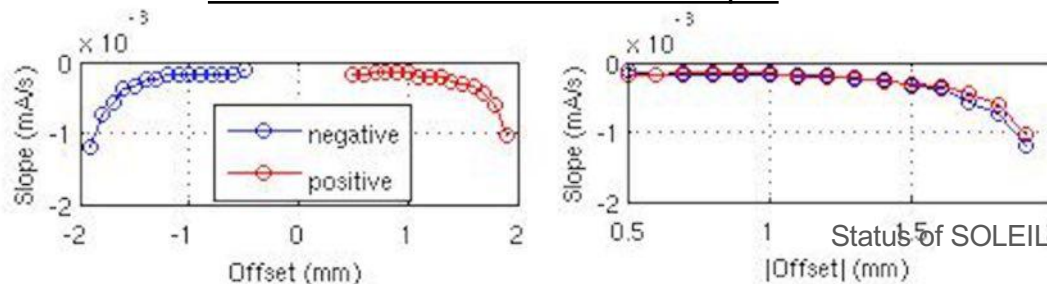
Minimal effects on the beam and
consistent with expectations



110 mA in 8 bunches :

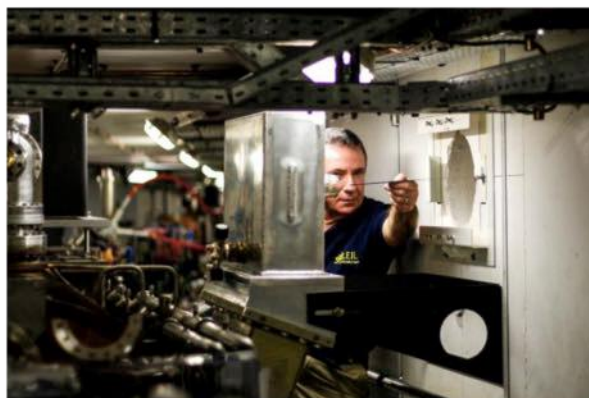
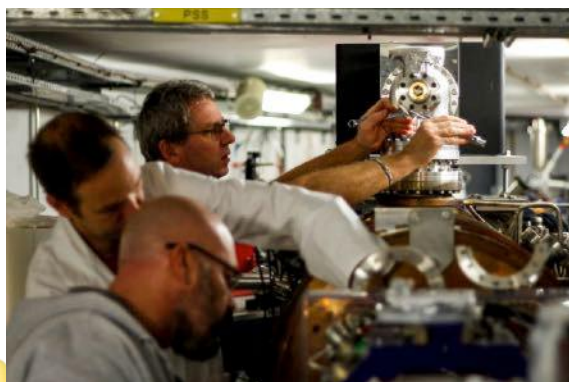
- Variation of 1.2 K only between different filling modes.
- No pressure rise.

Mechanical vertical offset of 25 μm



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



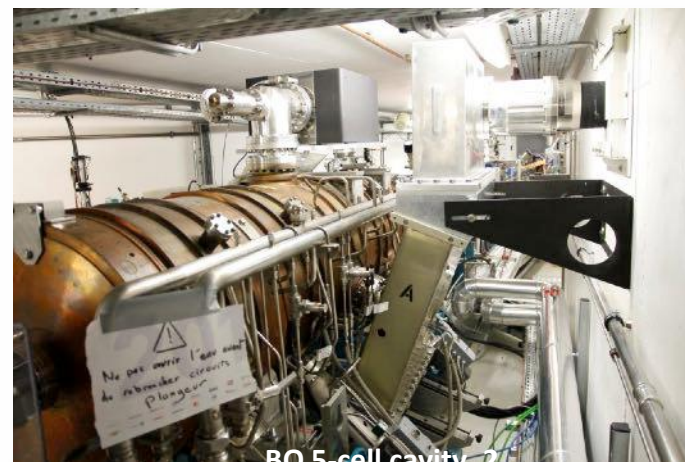
Implement a 2nd RF station → Increase V_{RF} from 1 up to 3 MV → Double injection efficiency



- 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 → $P_{RF} \sim 35$ kW ($P_{beam} \sim 0$) 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



BO 5-cell cavity_2



SSPA 1
35 kW

SSPA1
60 kW



Power converter operation: Availability is crucial [$A = \text{MTBF} / (\text{MTBF} + \text{MTTR})$]

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 additional 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**

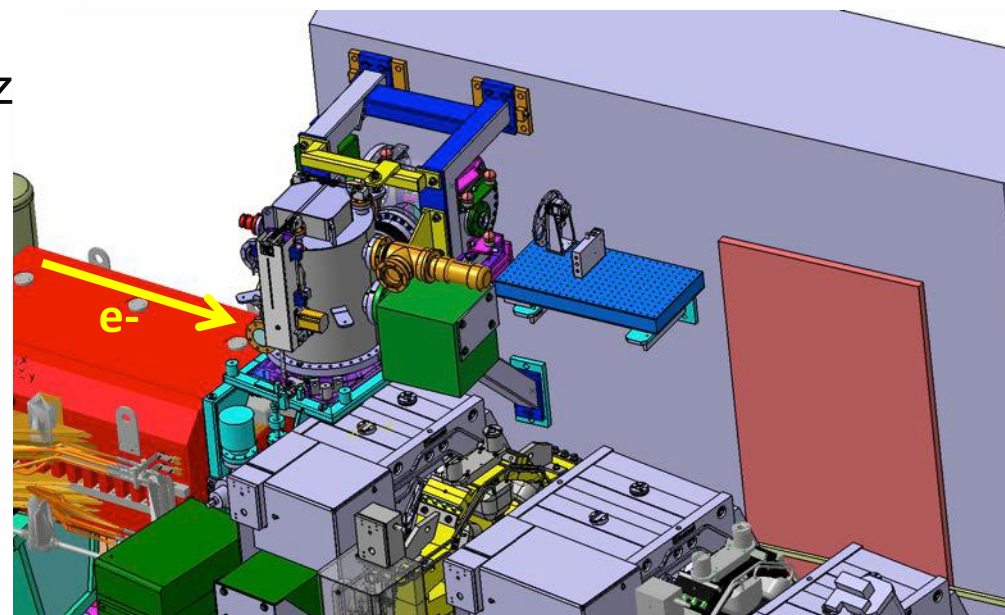


Beamline components (all in tunnel):

- 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



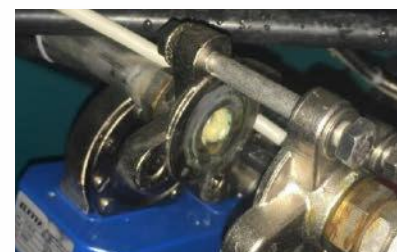
HU640



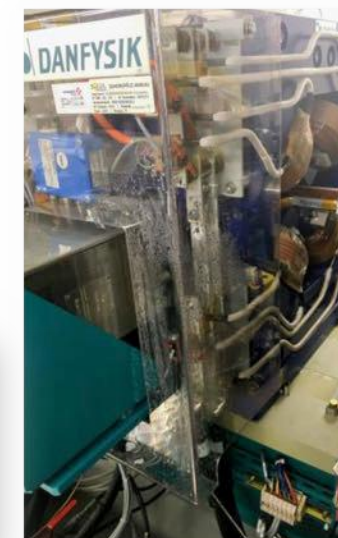
HU640 brazing joint



Clogging @ Filter

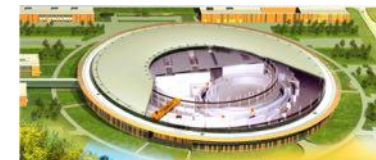


Whitish residue



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 ($P_{\text{mod}} : 310 \text{ W} \rightarrow 450 \text{ W}$) → 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



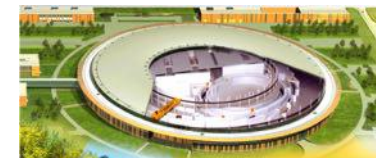
Present Status: 1.5 refurbished SSPA (6 towers, ~ 1000 modules)

→ 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**

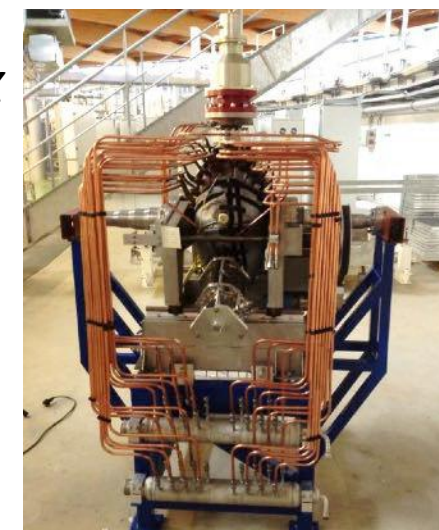
- **ThomX 3 GHz LINAC & 500 MHz SR RF system (Cavity, 60 kW SSPA, LLRF, FBT)**

- All the equipment delivered end of 2017
- Installation & commissioning → 2018 – 2019

- **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)

**ThomX
cavity**



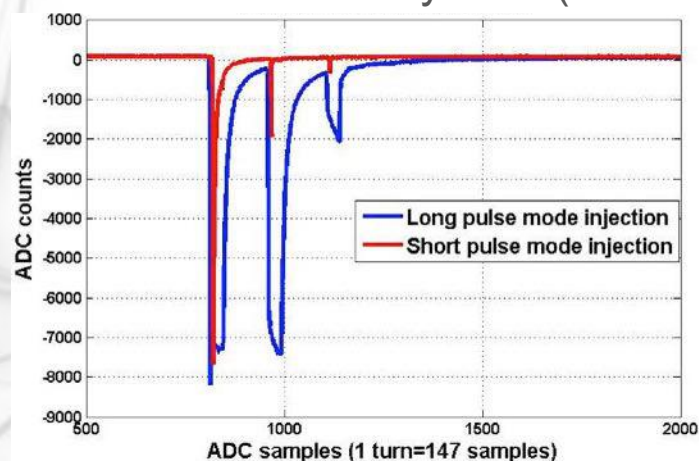
- **Preliminary study of the RF system for the upgrade of SOLEIL towards a DLSR – VSR**
 - Main 352 MHz system with longitudinal phase kick for on-axis injection
 - Harmonic RF systems for bunch lengthening and shortening



New Beam Loss Monitors

- **Objectives:**

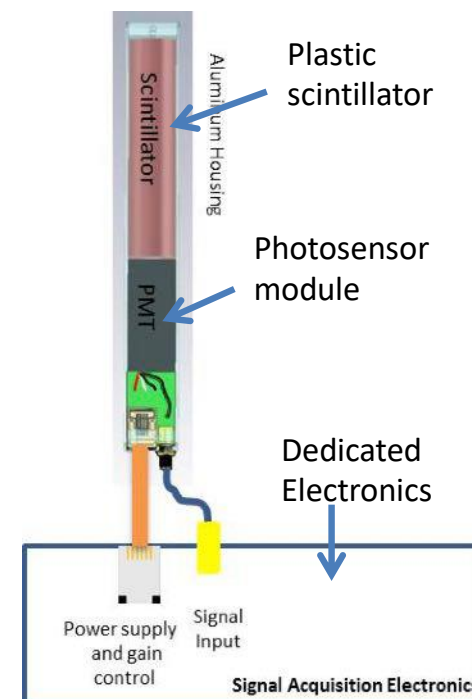
- Measurement of fast and slow losses with the same system.
- Improvement of the relative calibration between modules.
- Improvement (reduction) of the sensor directivity, compared to the current system (coincidence pin diodes).



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.



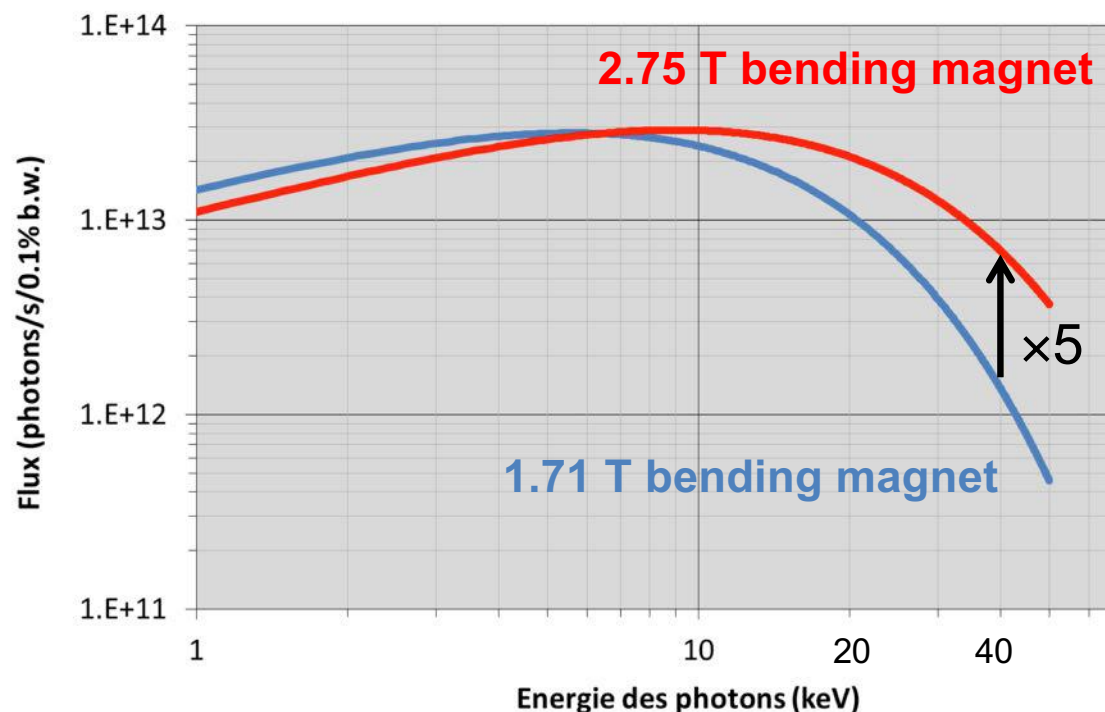
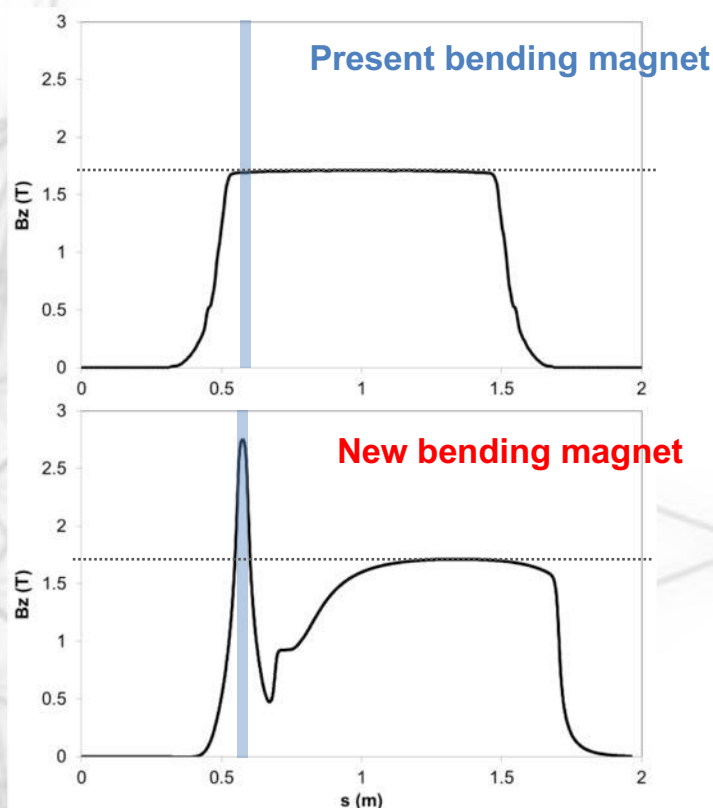
4 BLM installed behind the vertical scraper.



- 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



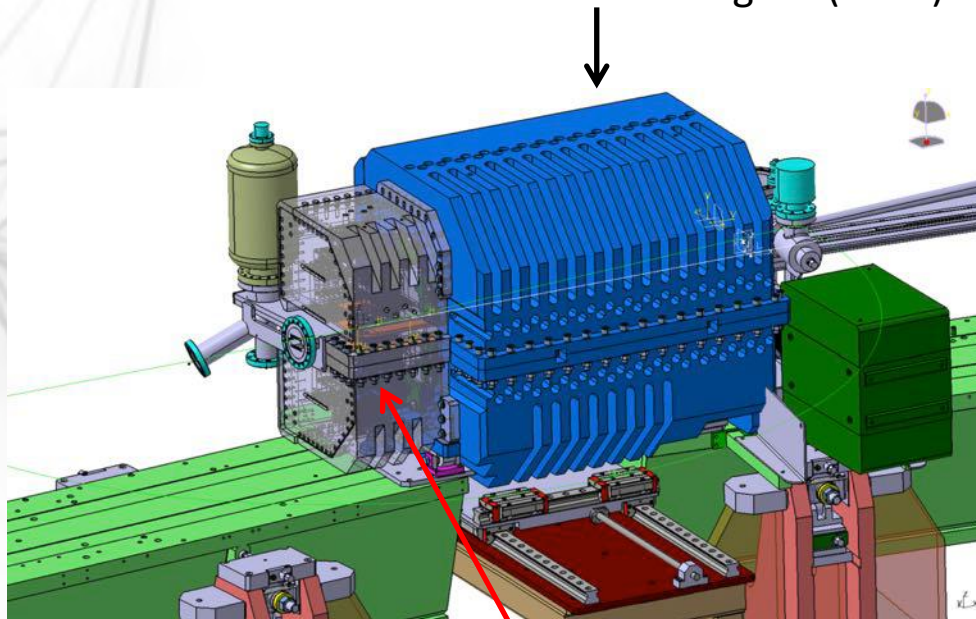
➤ **New bending magnet to be installed in August 2020**

Photon flux calculated at 8700 mm from the source point in an aperture of $3 \times 2.4 \text{ mm}^2$

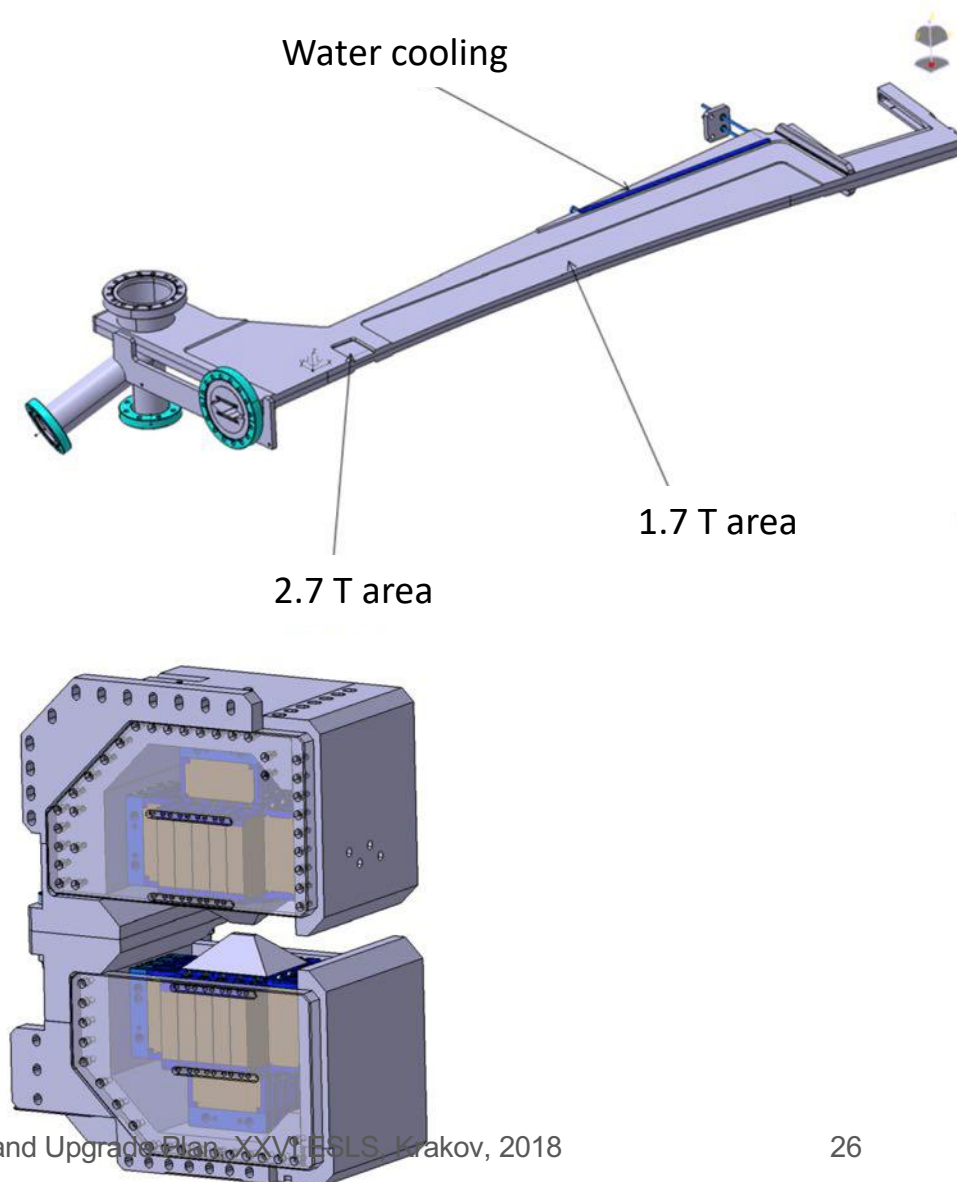
ROCK Beamline: Progress in the design of the magnet and the vacuum chamber

Magnet Ensemble design

Low field Magnet (1.7 T)



High field Magnet (2.7 T)

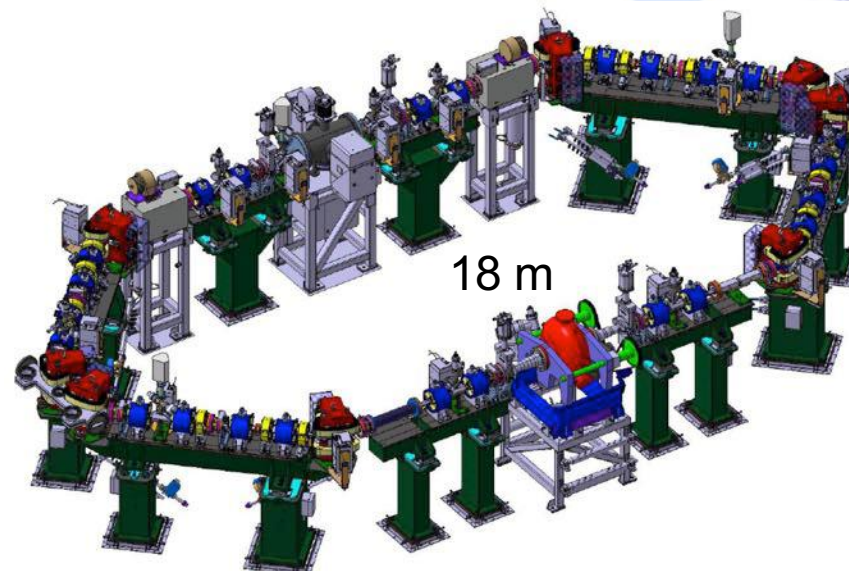


Compton Back Scattering X-ray Source

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

Commissioning :

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

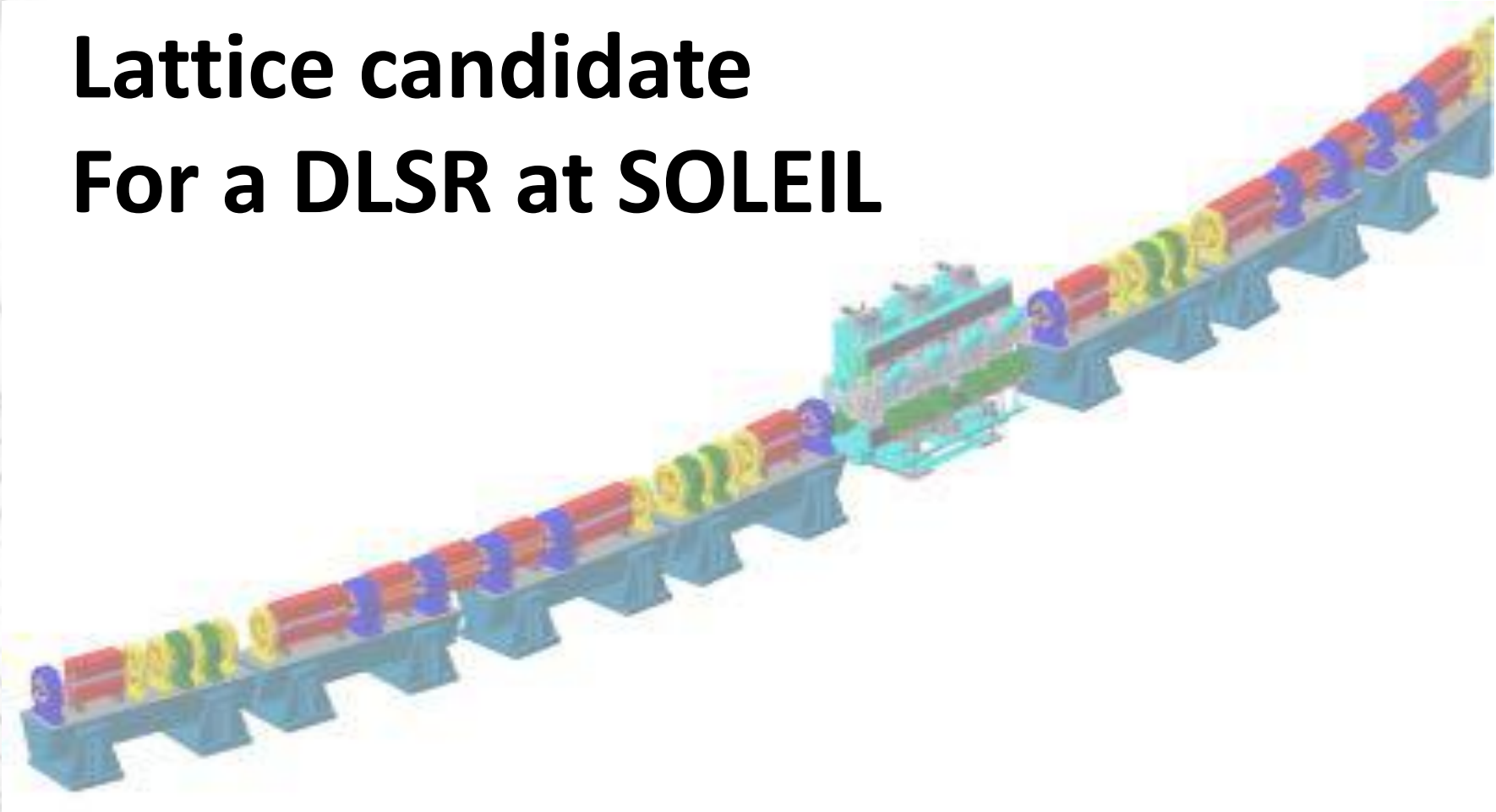


5019 hours for the beamlines

janv 2019			févr 2019			mars 2019			avr 2019			mai 2019			juin 2019			juil 2019			août 2019			sept 2019			oct 2019			nov 2019			déc 2019			janv 2020			févr 2020																									
mar 01			ven 01	M	V	M	ven 01				lun 01	A	A	Tv	mer 01				sam 01	M	M	M	lun 01	A	A	A	jeu 01				dim 01	A	A	A	mar 01	B	B	B	ven 01	S	S	S	dim 01	M	M	M	mer 01				sam 01	M	M	M										
mer 02			sam 02	M	M	M	sam 02				mar 02	B	B	B	jeu 02		18		dim 02	M	M	M	mar 02	Cp	Cp	B	ven 02				31				lun 02	A	A	A	mer 02	M	M	M	sam 02	S	S	S	lun 02	A	A	Tv	jeu 02				dim 02	M	M	M						
jeu 03			dim 03	M	M	M	dim 03				mer 03	M	M	M	ven 03				lun 03	A	A	A	mer 03	M	M	M	sam 03								mar 03	B	B	B	jeu 03	M	M	M	dim 03	S	S	S	mar 03	B	B	B	ven 03				lun 03	A	A	Tv						
ven 04			lun 04	A	A	Tv	lun 04				jeu 04	M	M	M	sam 04				mar 04	L	L	L	jeu 04	M	V	M	dim 04								mer 04	M	M	M	ven 04	A	A	Tv	mer 04	M	M	M	sam 04				mar 04	B	B	F										
sam 05			mar 05	B	B	B	mar 05				ven 05	M	M	M	dim 05				mer 05	L	L	L	ven 05	M	M	M	lun 05								jeu 05	M	M	M	mar 05	B	B	B	jeu 05	M	M	M	dim 05				mer 05	M	M	M										
dim 06			mer 06	M	M	M	mer 06				sam 06	M	M	M	lun 06				jeu 06				sam 06	M	M	M	mar 06								ven 06	M	M	M	dim 06	M	M	M	mer 06	M	M	M	ven 06	M	M	M	lun 06				jeu 06	M	M	M						
lun 07			jeu 07	M	M	M	jeu 07			A	dim 07	M	M	M	mar 07				ven 07	L	L	L	dim 07	M	M	M	mer 07								sam 07	M	M	M	lun 07	A	A	A	jeu 07	M	M	M	sam 07	M	M	M	mar 07				ven 07				06					
mar 08			ven 08	M	M	M	ven 08	A	A	A	lun 08	A	A	Tv	mer 08				sam 08	L	L	L	lun 08	A	A	Tv	jeu 08								dim 08	M	M	M	mar 08	L	L	L	ven 08	M	M	M	dim 08	M	M	M	mer 08				sam 08	M	M	M						
mer 09			sam 09	M	M	M	sam 09	A	A	A	mar 09	B	B	B	jeu 09				dim 09	L	L	L	mar 09	B	B	B	ven 09								lun 09	A	A	Tv	mer 09	L	L	L	sam 09	M	M	M	lun 09	A	A	A	jeu 09				dim 09	M	M	M						
jeu 10			dim 10	M	M	M	dim 10	A	A	A	mer 10	M	M	M	ven 10				lun 10	A	A	Tv	mer 10	M	M	M	sam 10								mar 10	8	8	8	jeu 10	L	L	L	dim 10	M	M	M	mar 10	A	A	Tv	ven 10				lun 10	A	A	Tv						
ven 11			lun 11	A	A	Tv	lun 11	A	A	A	jeu 11	M	M	M	sam 11				mar 11	B	B	B	jeu 11	M	V	M	dim 11								mer 11	8	8	8	ven 11				dim 11				lun 11	A	A	A	mer 11	M	M	M	sam 11				mar 11	B	B	F		
sam 12			mar 12	B	B	B	mar 12	B	B	B	ven 12	M	M	M	dim 12				mer 12	M	M	M	ven 12	M	M	M	lun 12								jeu 12	8	8	8	sam 12	L	L	L	mar 12	Cp	Cp	B	jeu 12	M	M	M	dim 12				mer 12	M	M	M						
dim 13			mer 13	M	M	M	mer 13	M	M	M	sam 13	M	M	M	lun 13				jeu 13	M	M	M	sam 13	M	M	M	mar 13								ven 13	8	8	8	dim 13	L	L	L	mer 13	M	M	M	ven 13	M	M	M	lun 13				jeu 13	M	M	M						
lun 14			jeu 14	M	M	M	jeu 14	M	M	M	dim 14	M	M	M	mar 14				ven 14	M	M	M	dim 14	M	M	M	mer 14								sam 14	8	8	8	lun 14				jeu 14	M	M	M	sam 14	M	M	M	mar 14				ven 14	M	M	M						
mar 15			ven 15	M	M	M	ven 15	M	M	M	lun 15	A	A	Tv	mer 15				sam 15	M	M	M	lun 15	A	A	Tv	jeu 15								dim 15	8	8	8	mar 15				ven 15	M	M	M	dim 15	M	M	M	mer 15				sam 15	M	M	M						
mer 16			sam 16	M	M	M	sam 16	M	M	M	mar 16	B	B	B	jeu 16				dim 16	M	M	M	mar 16	B	B	B	ven 16								lun 16	A	A	Tv	mer 16				sam 16	M	M	M	lun 16	M	M	M	jeu 16	A	A	A	dim 16	M	M	M						
jeu 17	A	A	A	dim 17	M	M	M	dim 17	M	M	M	mer 17	M	M	M	ven 17	A	A	A	lun 17	A	A	Tv	mer 17	M	M	M	sam 17								mar 17	B	B	B	jeu 17				dim 17	M	M	M	mar 17	M	M	M	ven 17	A	A	A	mar 17				03				
ven 18			lun 18	A	A	Tv	lun 18	A	A	Tv	jeu 18	M	M	M	sam 18	A	A	A	mar 18	B	B	B	jeu 18	M	V	M	dim 18								mer 18	M	M	M	ven 18				lun 18	A	A	Tv	mer 18				sam 18	A	A	A	mar 18				mar 18				07	
sam 19	A	A	A	mar 19	B	B	B	mar 19	B	B	B	ven 19	M	M	M	dim 19	A	A	A	mer 19	M	M	M	ven 19	M	M	M	lun 19								jeu 19	38			sam 19	M	M	M	mar 19	B	B	B	jeu 19				dim 19	A	A	A	mer 19				jeu 19				08
dim 20	A	A	A	mer 20	M	M	M	mer 20	M	M	M	sam 20	M	M	M	lun 20	A	A	A	jeu 20	M	V	M	sam 20	M	M	M	mar 20								ven 20	40			dim 20	M	M	M	mer 20	M	M	M	ven 20				lun 20	A	A	A	jeu 20				01				
lun 21	A	A	A	jeu 21	M	M	M	jeu 21	M	M	M	dim 21	M	M	M	mar 21	S	S	S	ven 21	M	M	M	dim 21	M	M	M	mer 21								lun 21	42			lun 21	M	M	M	jeu 21	M	M	M	sam 21				mar 21	B	B	B	ven 21				02				
mar 22	B	B	B	ven 22	M	M	M	ven 22	M	M	M	lun 22	A	A	Tv	mer 22	S	S	S	sam 22	M	M	M	lun 22	A	A	Tv	jeu 22								dim 22	44			mar 22				ven 22	M	M	M	dim 22				mer 22	M	M	M	sam 22				03				
mer 23	M	M	M	sam 23	M	M	M	sam 23	M	M	M	mar 23	8	8	8	jeu 23	21			dim 23	M	M	M	mar 23	B	B	B	ven 23								lun 23	46			mer 23	48			sam 23	M	M	M	lun 23				jeu 23	M	M	M	dim 23				04				
jeu 24			dim 24	M	M	M	dim 24	M	M	M	mer 24	8	8	8	ven 24	S	S	S	lun 24	A	A	Tv	mer 24	M	M	M	sam 24								mar 24	48			jeu 24	50			dim 24	M	M	M	mar 24				ven 24	M	M	M	lun 24				05					
ven 25	M	M	M	lun 25				lun 25	A	A	A	jeu 25	8	8	8	sam 25	S	S	S	mar 25	B	B	B	jeu 25	M	V	M	dim 25								mer 25	52			ven 25	A	A	A	lun 25	A	A	Tv	mer 25				sam 25	M	M	M	mar 25				06				
sam 26	M	M	M	mar 26				mar 26	Cp	Cp	B	ven 26	8	8	8	dim 26	S	S	S	mer 26	M	M	M	ven 26	M	M	M	lun 26								jeu 26	54			sam 26	A	A	A	mar 26	B	B	B	jeu 26				dim 26	M	M	M	mer 26				07				
dim 27	M	M	M	mer 27				mer 27	M	M	M	sam 27	8	8	8	lun 27	A	A	Tv	jeu 27	M	M	M	sam 27	M	M	M	mar 27								ven 27	56			dim 27	A	A	A	mer 27	M	M	M	ven 27				lun 27	A	A	Tv	jeu 27				08				
lun 28	A	A	Tv	jeu 28				jeu 28	M	M	M	dim 28	8	8	8	mar 28	B	B	B	ven 28	M	M	M	dim 28	M	M	M	mer 28								lun 28	58			mar 28	A	A	A	jeu 28	M	M	M	sam 28				mar 28	B	B	B	ven 28	A	A	A	09				
mar 29	B	B	B					ven 29				lun 29				mer 29	M	M	M	sam 29	M	M	M	lun 29				jeu 29	A	A	A					mer 29	60			ven 29	S	S	S	dim 29				mer 29	M	M	M	sam 29	A	A	A	00								
mer 30	M	M	M					sam 30	M	M	M	mar 30				jeu 30	M	V	M	dim 30	M	M	M	mar 30				ven 30	A	A	A					lun 30	62			mer 30	S	S	S	sam 30	M	M	M	lun 30				jeu 30	M	M	M	01								
jeu 31	M	M	M					dim 31	M	M	M	mar 31				ven 31	M	M	M					mer 31				sam 31	A	A	A					jeu 31	64			dim 31	M	M	M	mar 31				ven 31	M	M	M	02												

- 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

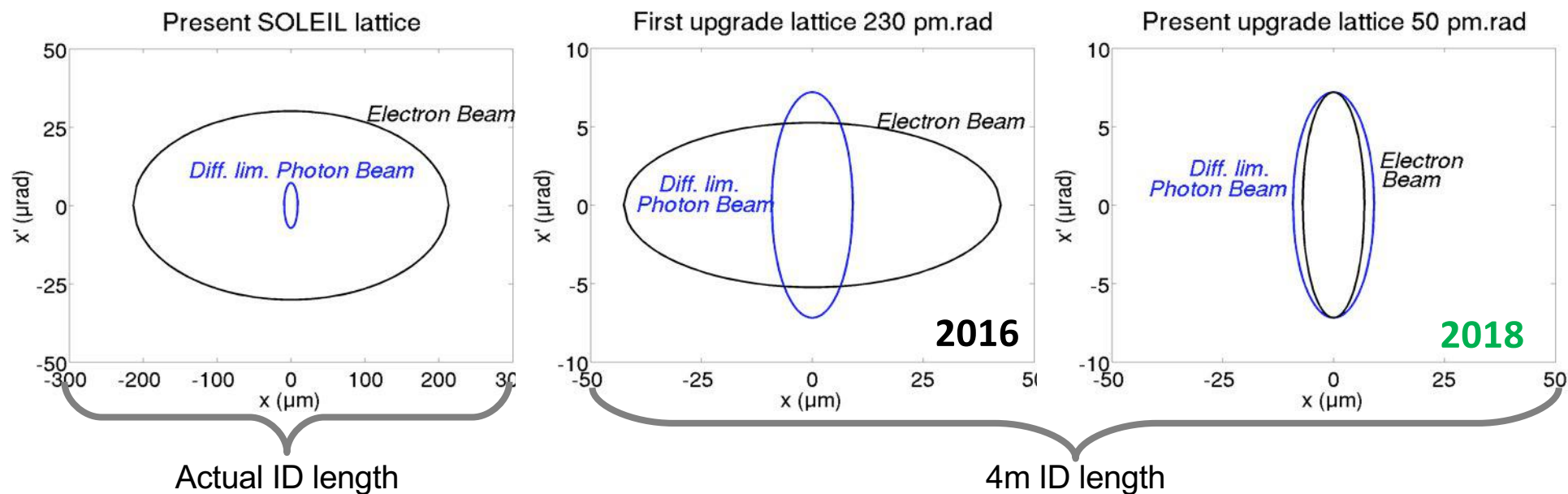


Boundary Conditions and Constraints

- 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: \leq **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.

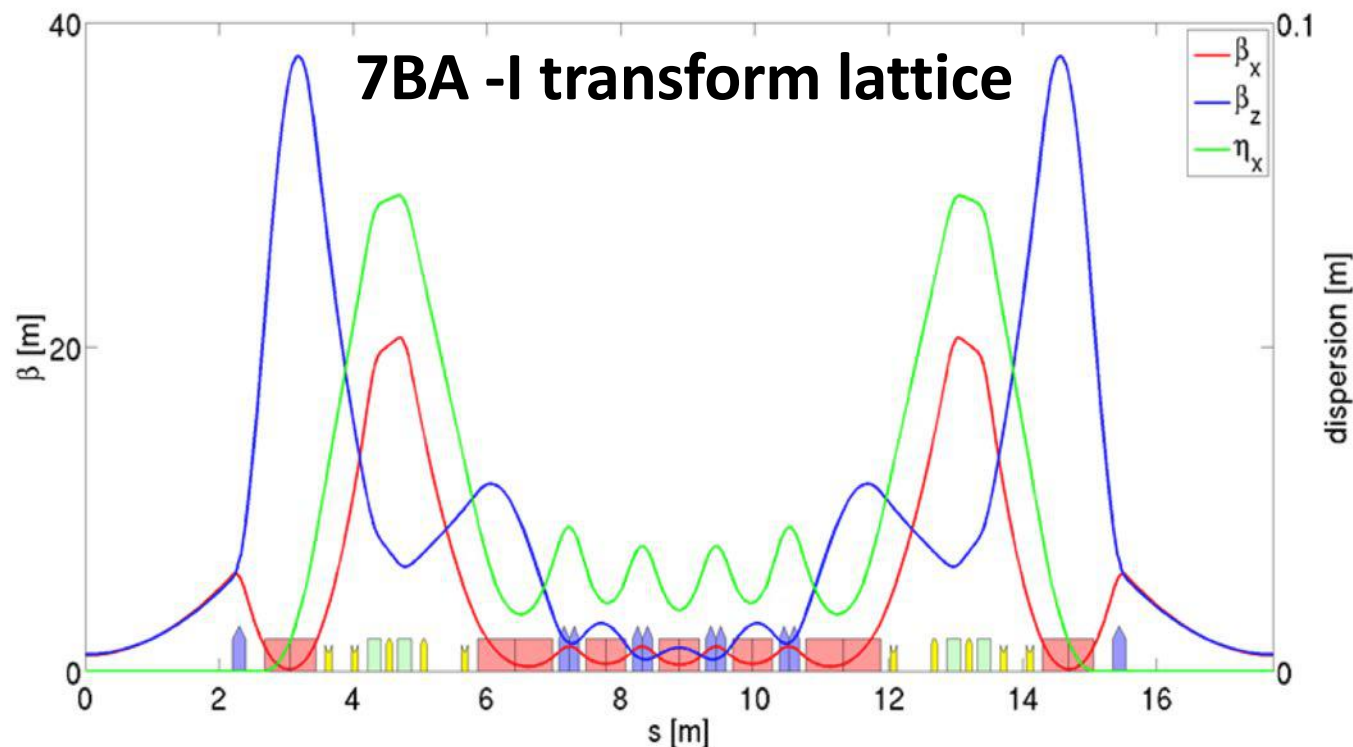


New Lattice Candidate

$\epsilon_x = 72 \text{ pm.rad}$ 20 cells – 20 straights sections
 $L_{SS} = 4.4 \text{ m}$ avec $\beta_x = \beta_z = 1 \text{ m}$

2.75 GeV
 354 m

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

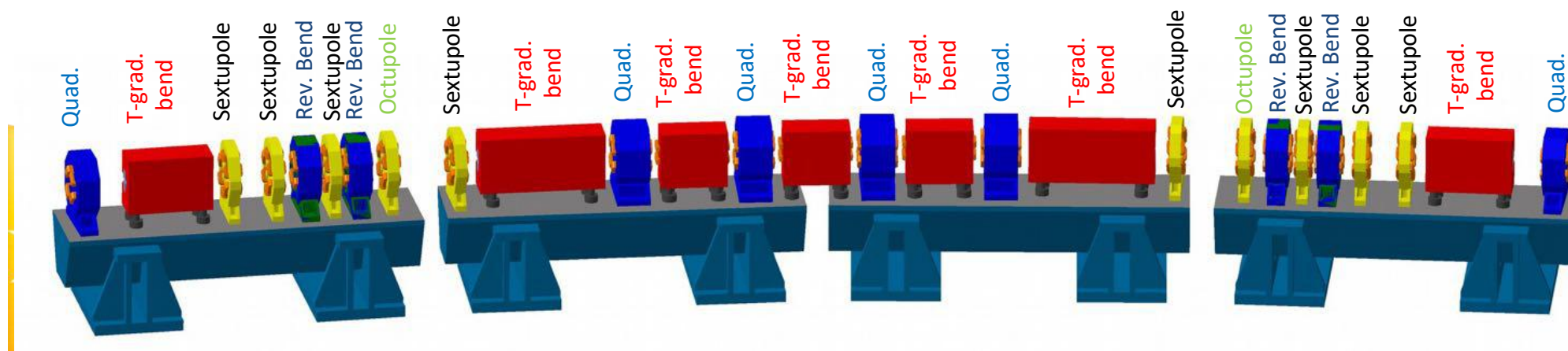


- Sext $< 2000 \text{ T/m}^2$
- Quad $< 100 \text{ T/m}$
- Dip $\sim 0.6 \text{ T}$ & 40 T/m

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

Use of anti-bends
 Use of gradient dipoles

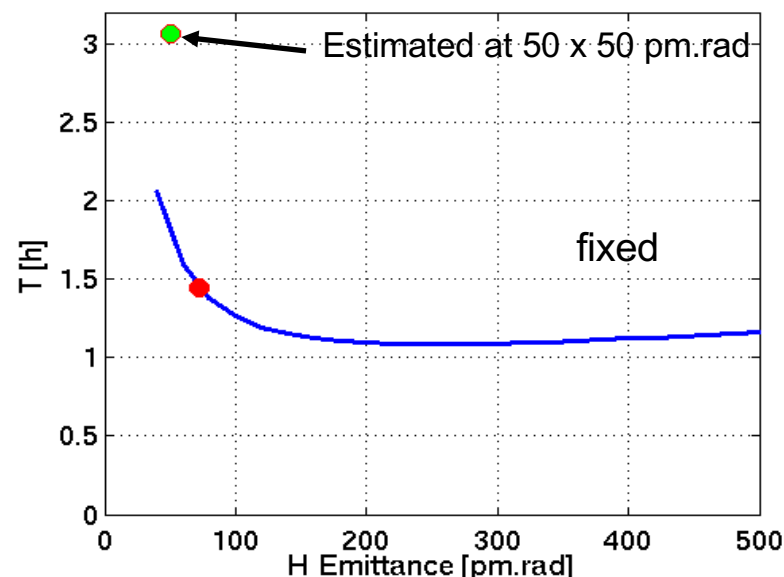
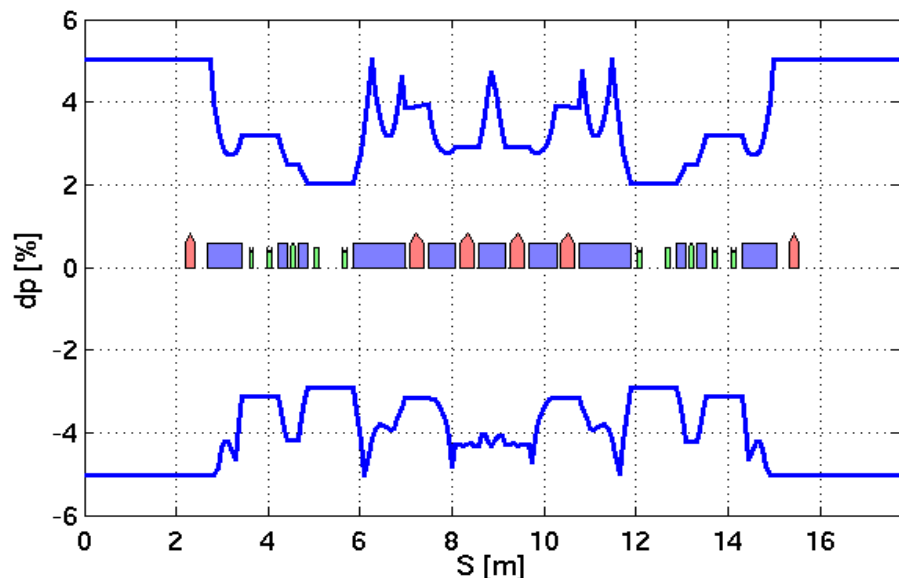
No longitudinal gradient in
 dipoles



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

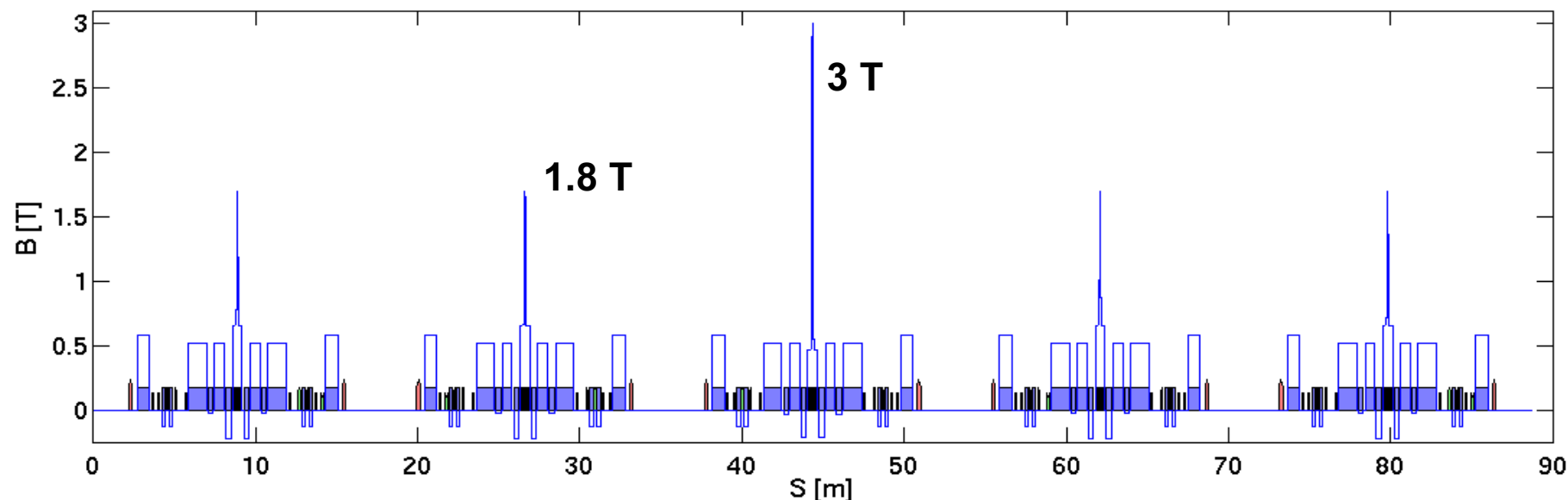
Limited IBS Effect

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



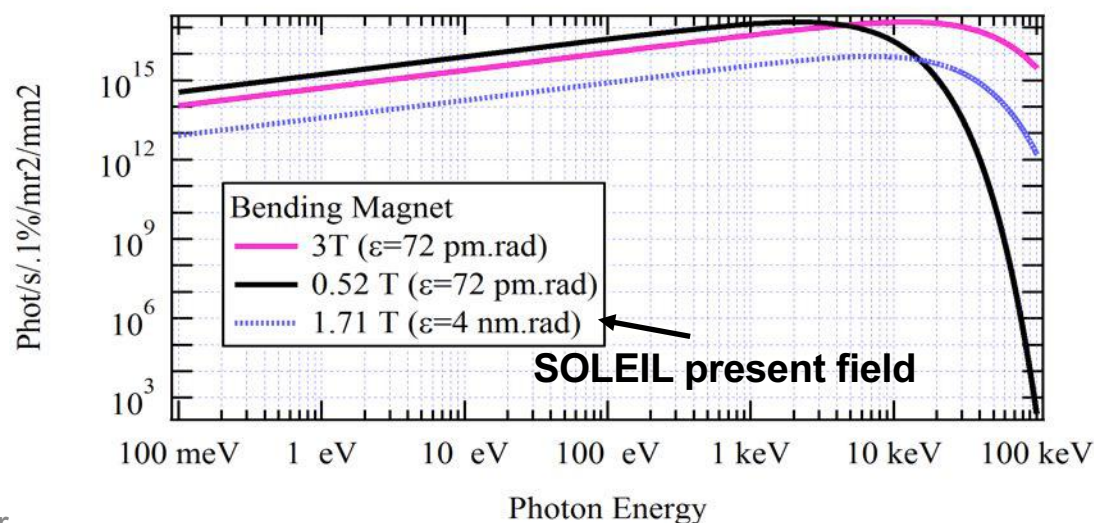
Add 1.8 T on central bend of other cells to reduce back the emittance ~ **70 pm.rad**

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

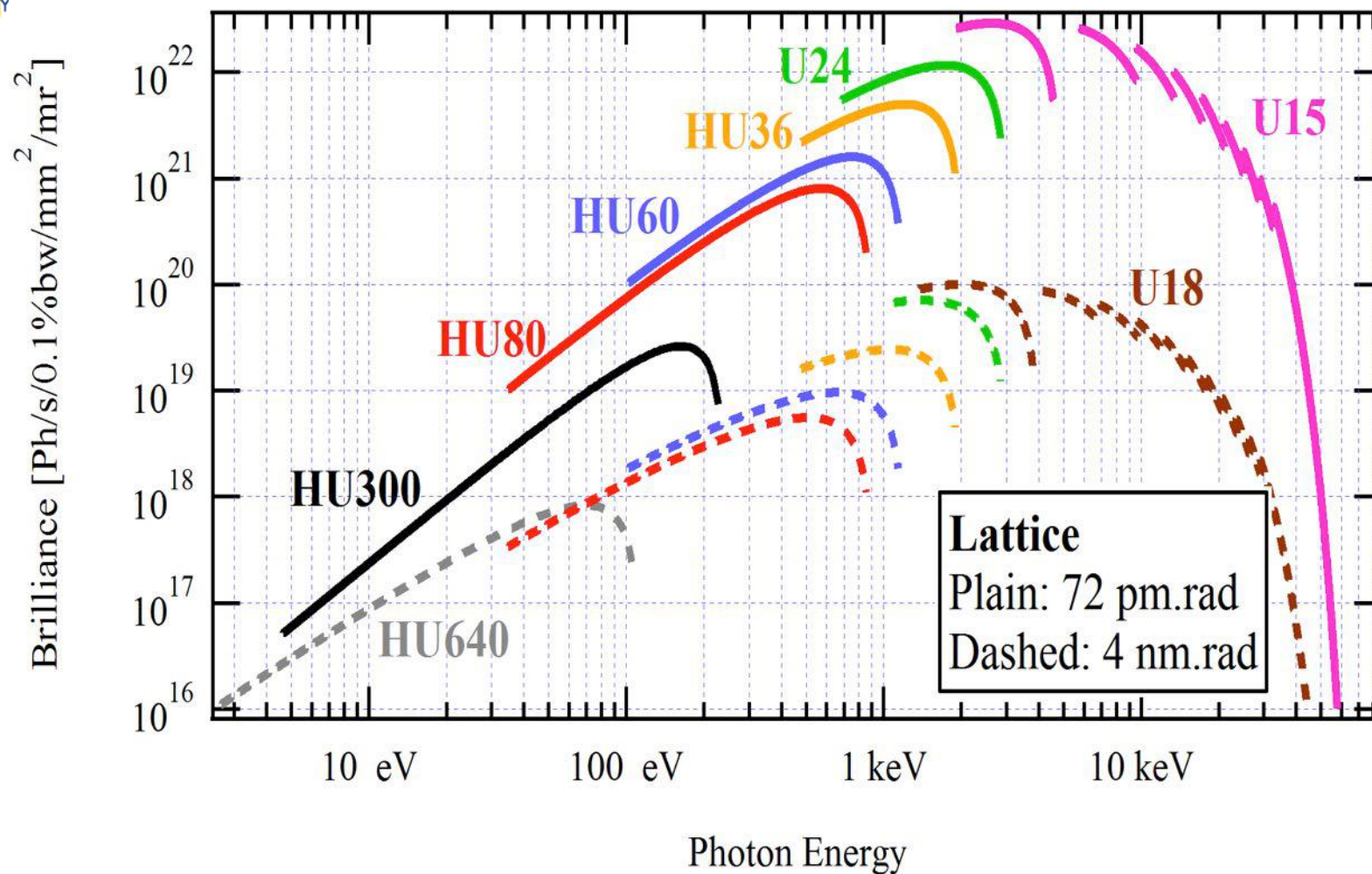
To **increase the photon flux above 10 keV**

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

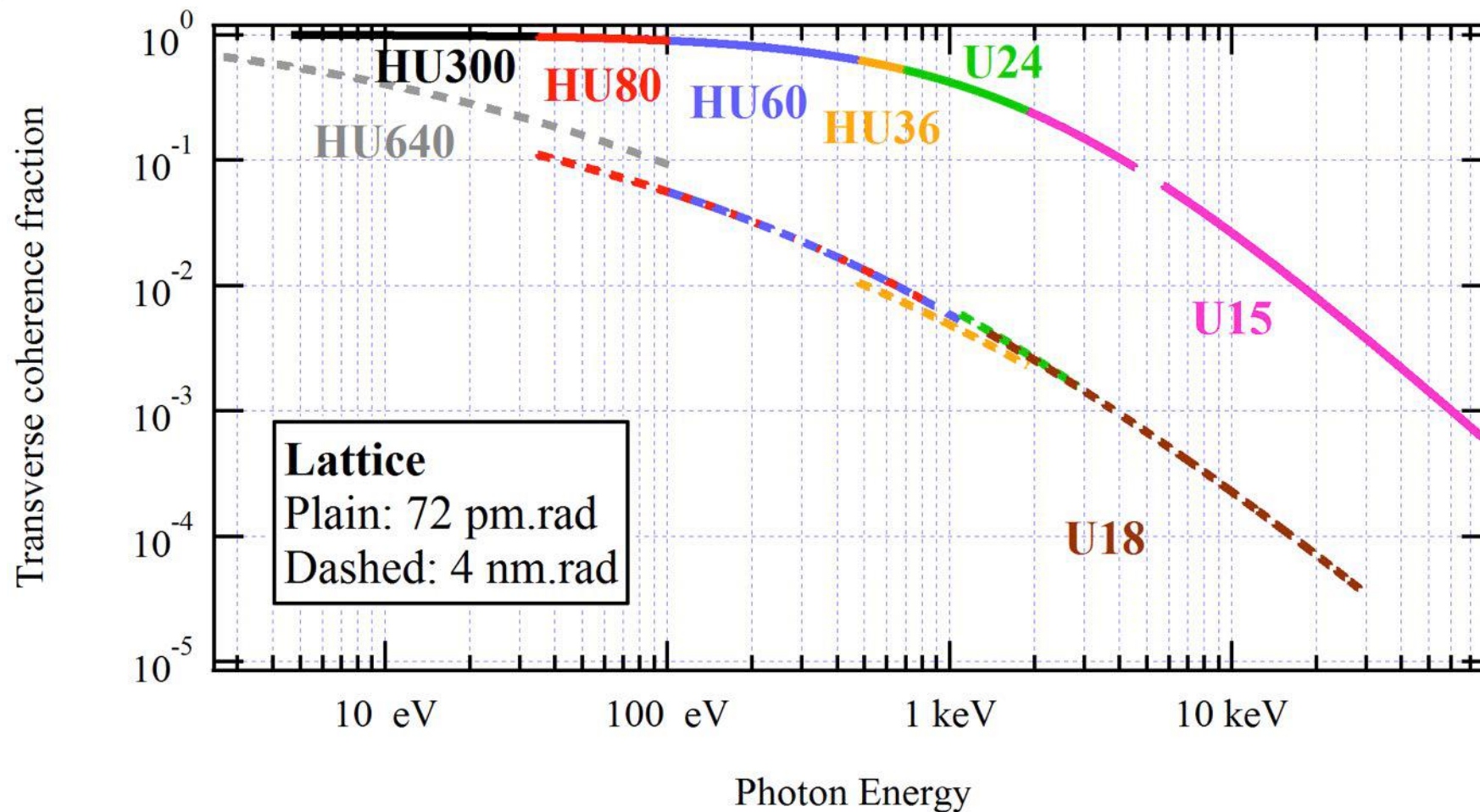


The brilliance increase reaches **two orders** of magnitude in the region of interest:

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

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

Transverse Beam Coherence



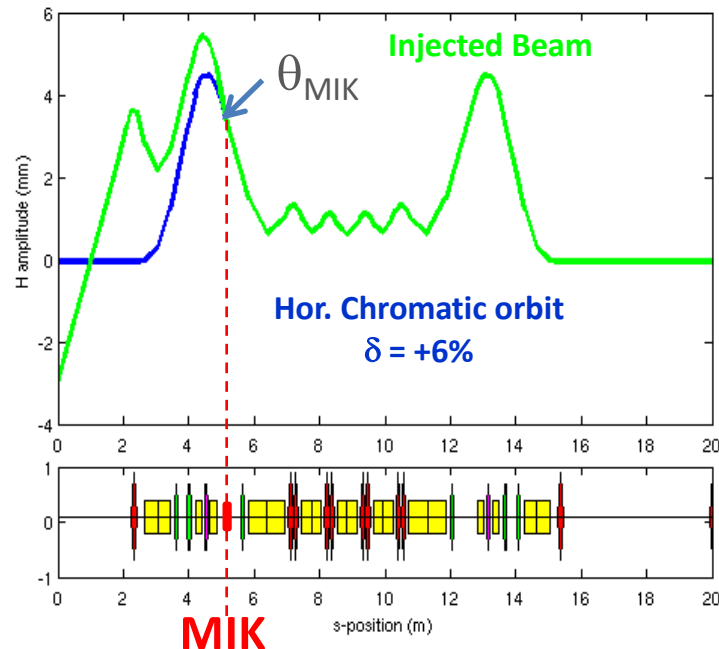
The photon beam should be **fully coherent** up to **almost 200 eV**, exceeding **40%** at **1 keV** and reaching **14%** at **3 keV**



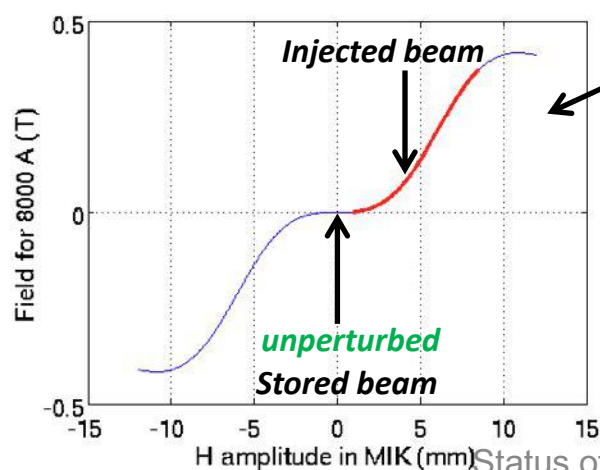
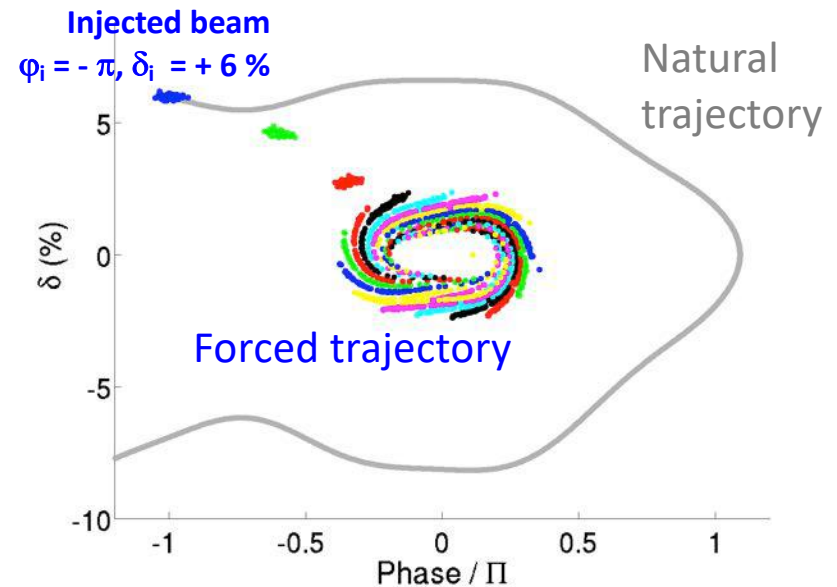
Longitudinal Injection on Chromatic Orbit with a NLK and an Extra Transient RF Pulse

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) ...



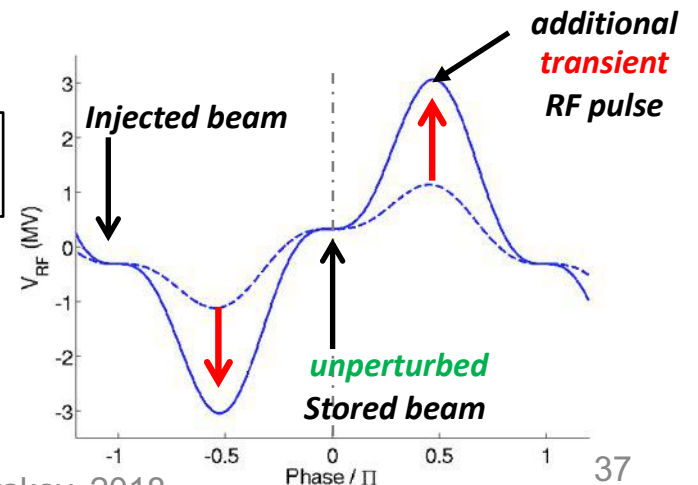
... and launched from an offset phase ($-\pi$), its energy is damped thanks to a **transient RF pulse** (main and harmonic)



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

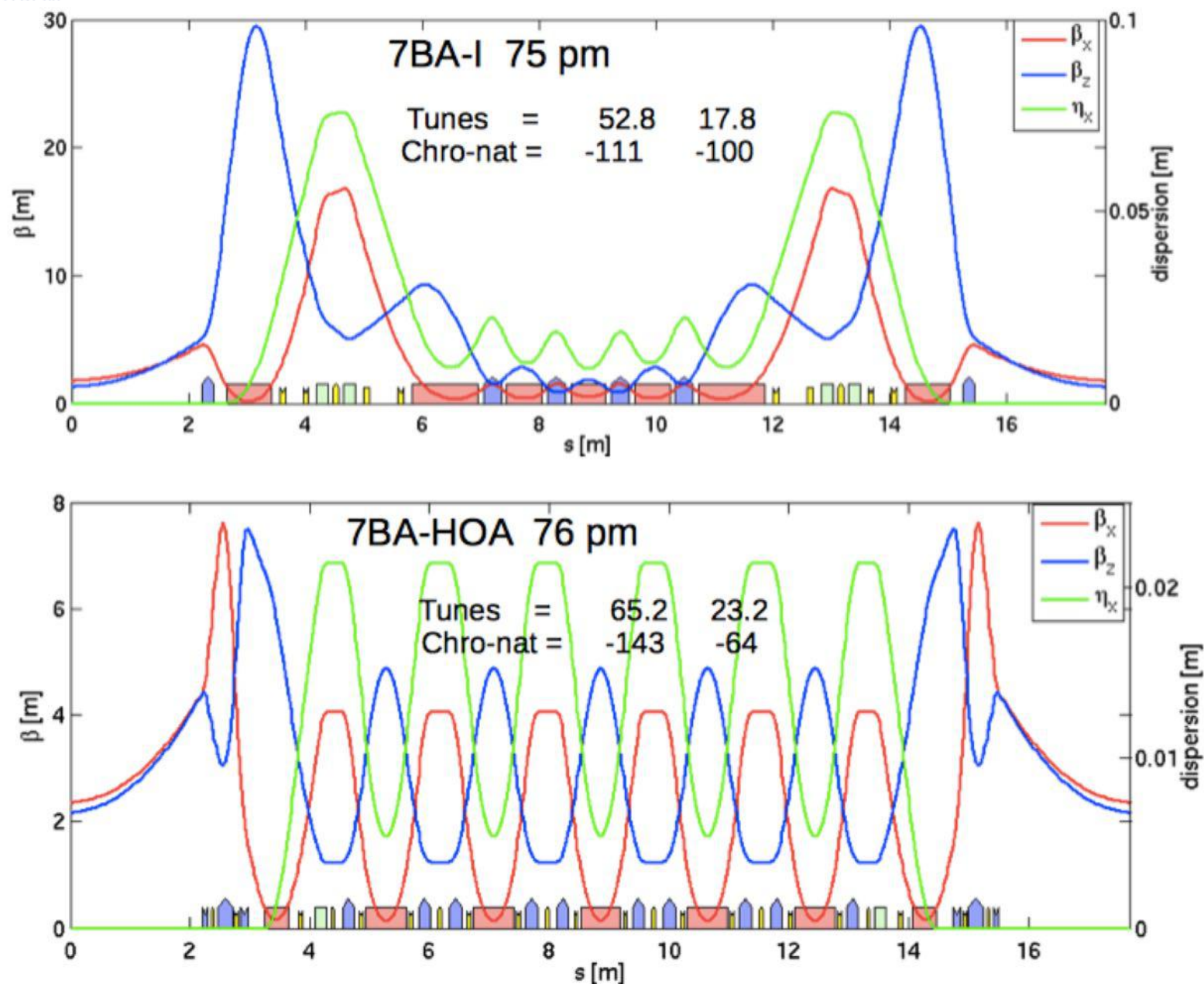


- **Breaking the symmetry 20 (Straight Section of 4.4m)**
 - Solution with Symmetry 4: **75 pm.rad**
 - Accommodating **6 m/4 m** straight sections
 - **Included canted in-vacuum undulators**
- **Preserving the low emittance: 74 pm.rad**
 - High Order Achromat to third order: 7BA-HOA lattice

LATTICE ALTERNATIVES

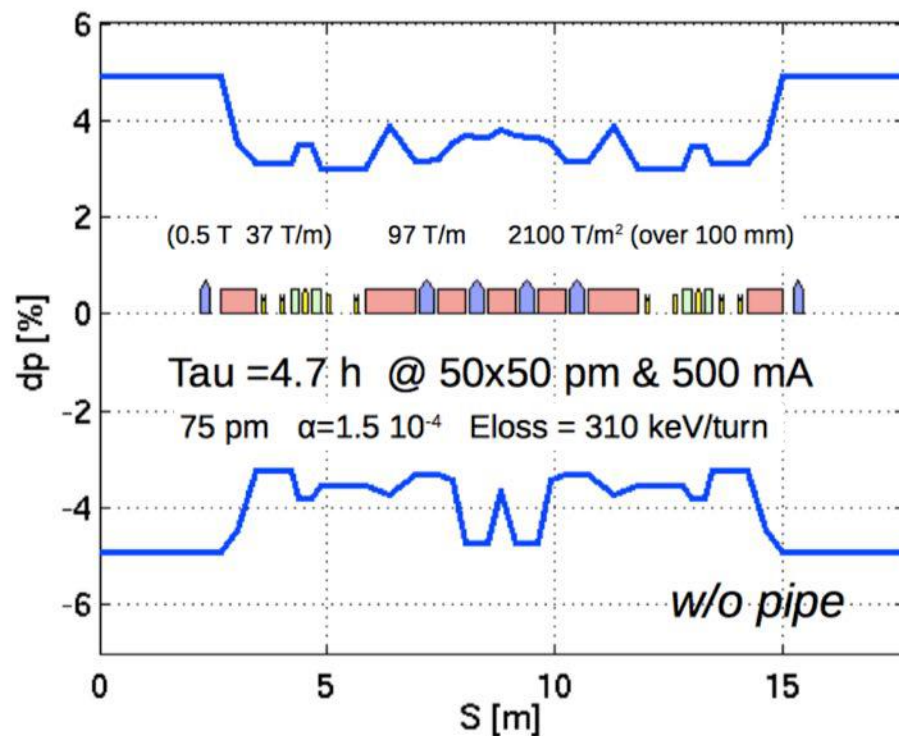


7BA-HOA lattice option



Momentum Acceptance

7BA-I-transform 75 pm



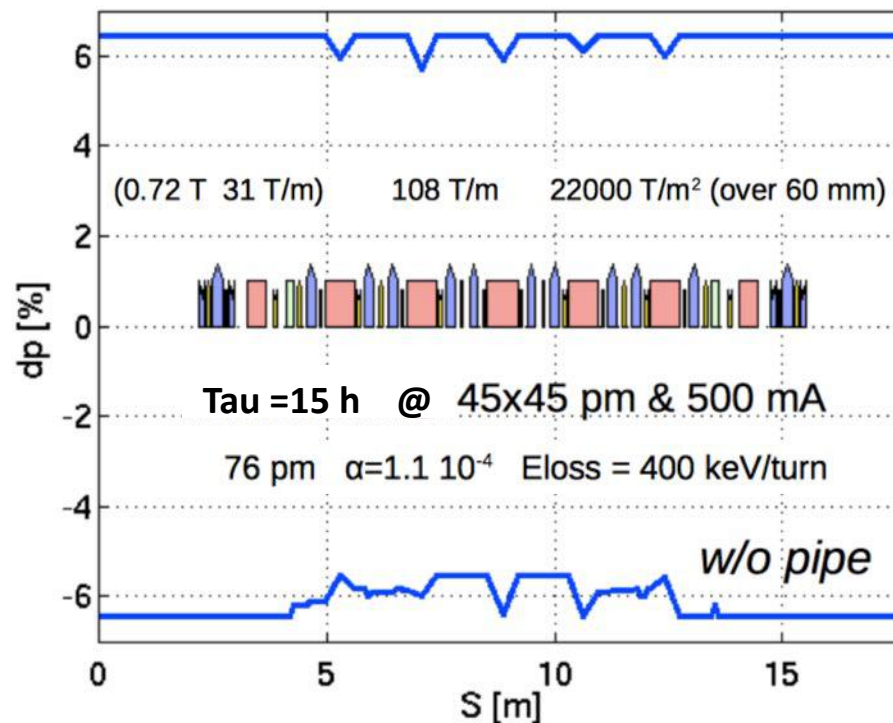
$$\sigma_s = 3.7 \text{ mm}$$

$$V_{rf} = 1.1 \text{ MV}$$

$$\phi_s = 0.28 \text{ rad}$$

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

7BA-HOA 76 pm



$$\sigma_s = 2.5 \text{ mm}$$

$$V_{rf} = 1.4 \text{ MV}$$

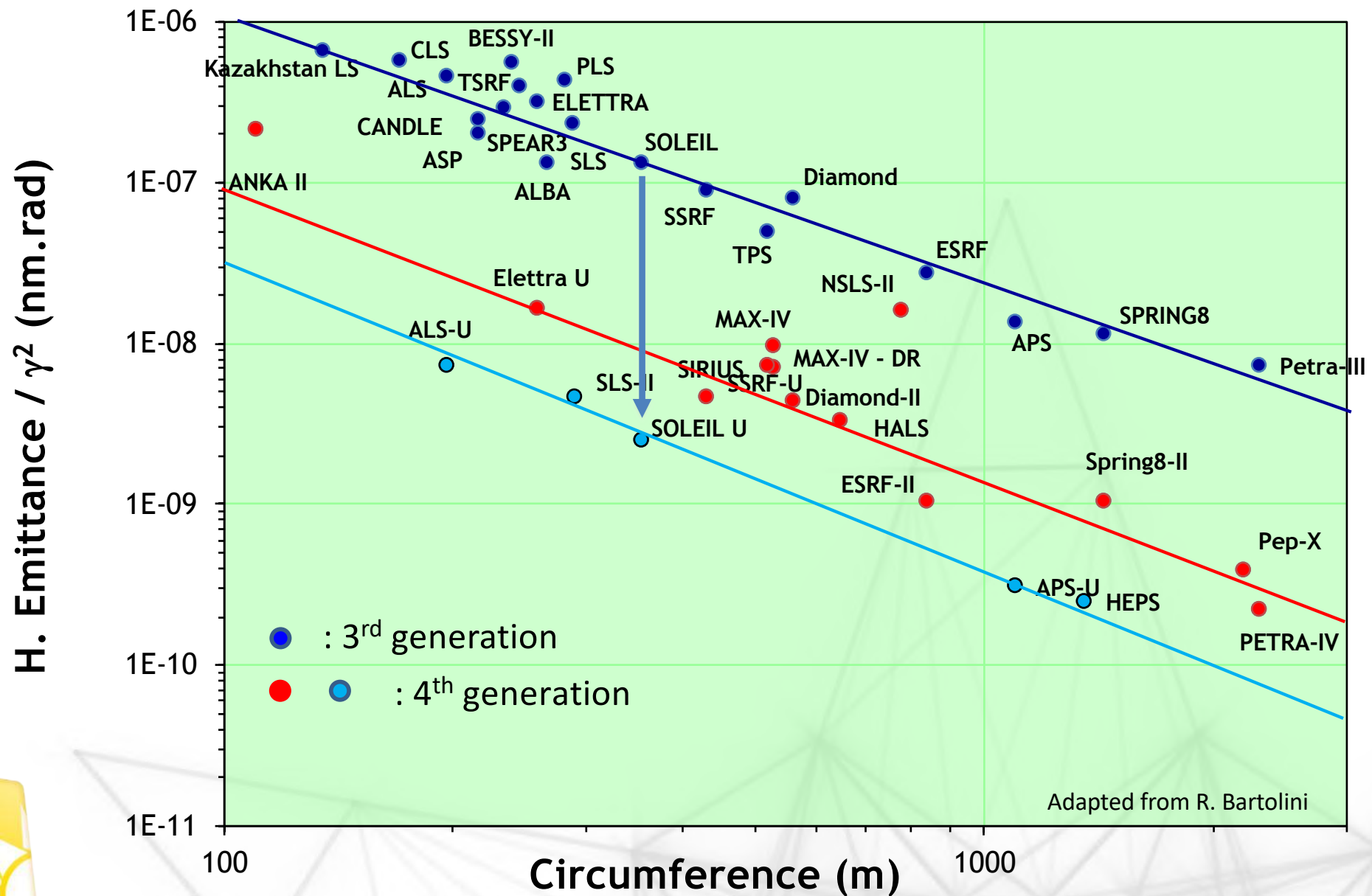
$$\phi_s = 0.28 \text{ rad}$$

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 Chromaticities	-53/-19	-120/-127	-142/-64
Momentum Compaction α_1	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, ϵ_V/ϵ_H	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



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/mm²/mrad²/0.1%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 ?

