JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

Status of SOLARIS

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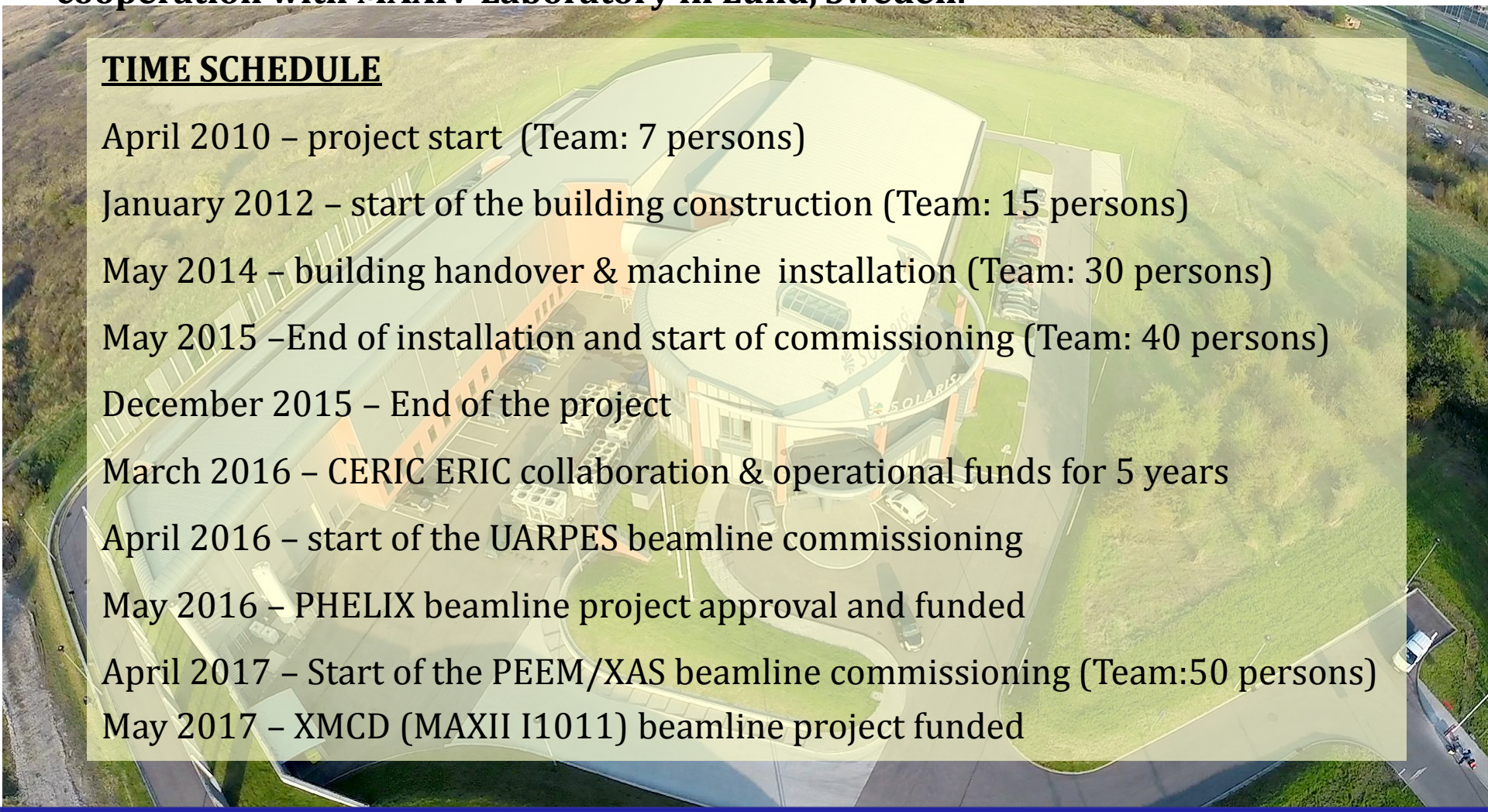
OUTLINE

- Facility Introduction
- Operation schedule
- Storage Ring Parameters
- Beam Stability
- Recent Failures
- Beamlines Status
- Future activities

3rd generation light source facility built at the Jagiellonian University Campus in Krakow, Poland. The machine was constructed in 2015 thanks to the unique cooperation with MAXIV Laboratory in Lund, Sweden.



TIME SCHEDULE

April 2010 – project start (Team: 7 persons)

January 2012 – start of the building construction (Team: 15 persons)

May 2014 – building handover & machine installation (Team: 30 persons)

May 2015 –End of installation and start of commissioning (Team: 40 persons)

December 2015 – End of the project

March 2016 – CERIC ERIC collaboration & operational funds for 5 years

April 2016 – start of the UARPES beamline commissioning

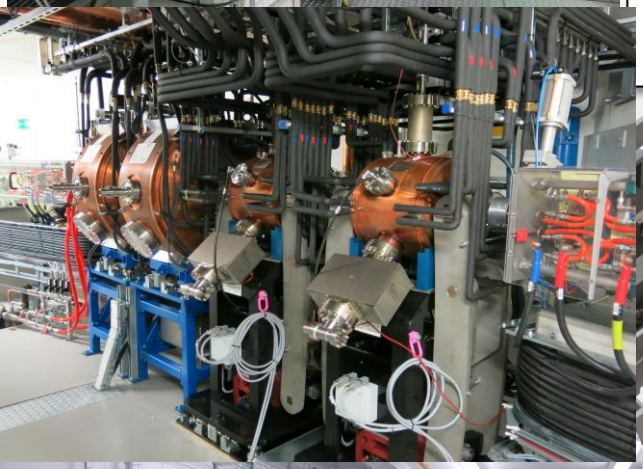
May 2016 – PHELIX beamline project approval and funded

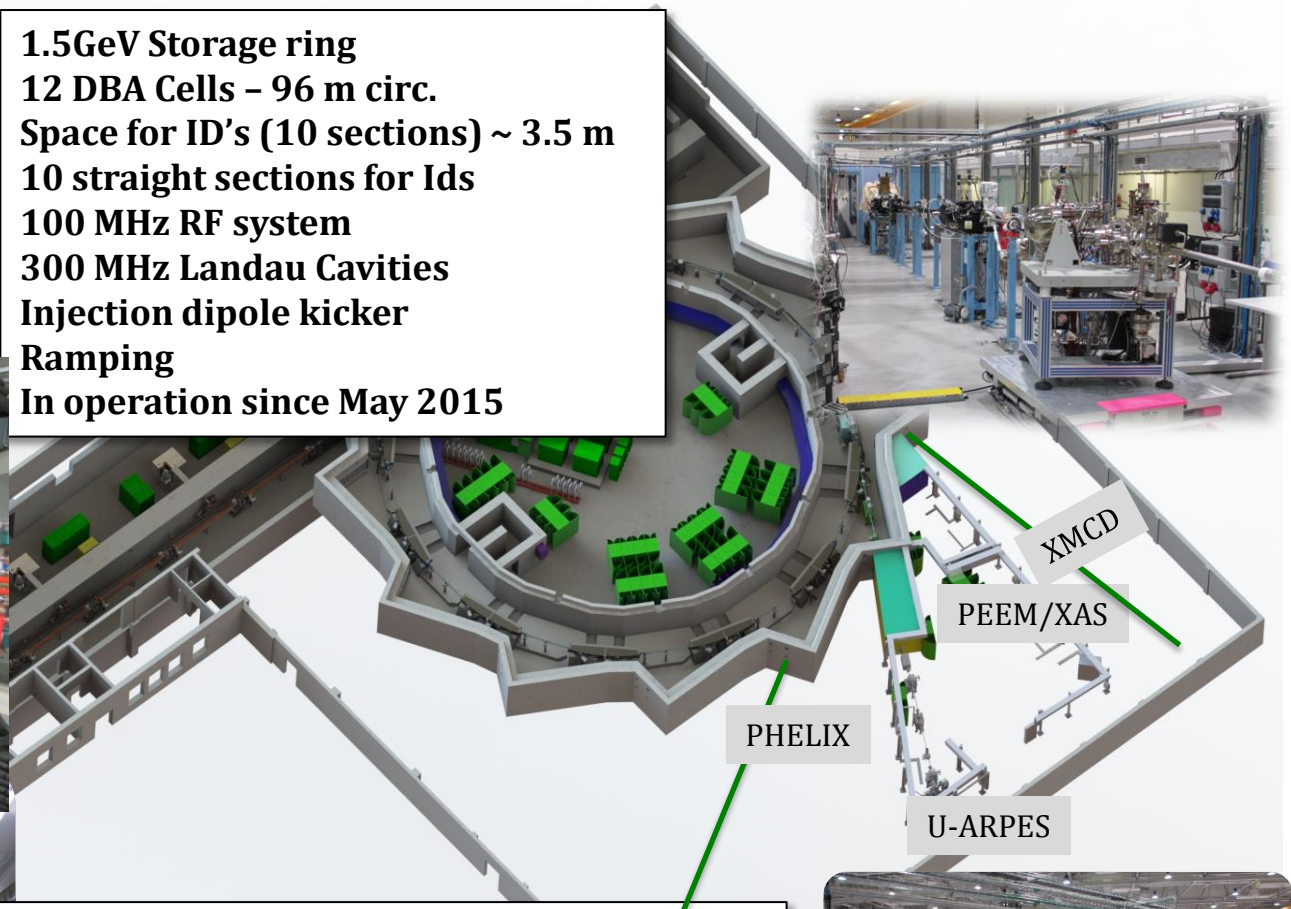
April 2017 – Start of the PEEM/XAS beamline commissioning (Team:50 persons)

May 2017 – XMCD (MAXII I1011) beamline project funded

SOLARIS - LAYOUT

1.5GeV Storage ring
12 DBA Cells – 96 m circ.
Space for ID's (10 sections) ~ 3.5 m
10 straight sections for Ids
100 MHz RF system
300 MHz Landau Cavities
Injection dipole kicker
Ramping
In operation since May 2015

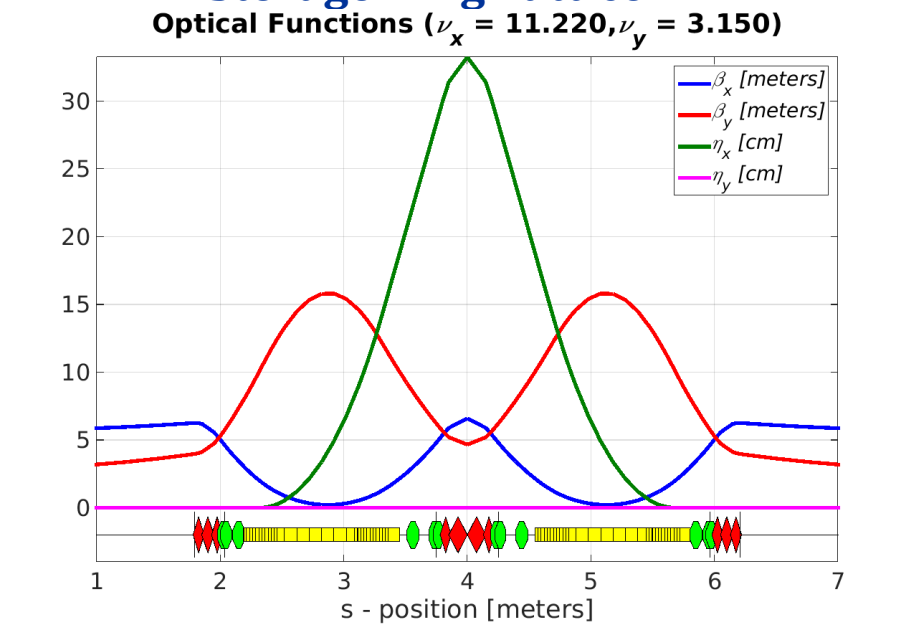




600 MeV Linac with RF Thermionic Gun
6 accelerating structures combined in 3 units
Accelerating gradient 20 MeV/m
S-band – 2998.5 MHz
3 RF Units & SLED cavities
In operation since Dec. 2014

STORAGE RING

Storage Ring Lattice



Electron energy	1.5 GeV
Design current	500 mA
Number of circulating bunches	32
Natural bunch length σ_z /w. Landau Cavities (LC)	14.2 mm /60 mm
Natural emittance (bare lattice)	5.982 nmrad
Coupling	1 %
Energy spread (bare lattice)	0.000745
Tunes ν_x, ν_y	11.22, 3.15
Natural chromaticities ξ_x, ξ_y	-22.96, -17.14
Corrected chromaticities ξ_x, ξ_y	+1, +1
Momentum compaction	3.055×10^{-3}
Energy loss/turn	114.1 keV
Momentum acceptance	4%

MAXIV Facility, DDR, § 3, http://www.maxlab.lu.se/maxlab/max4/DDR_public

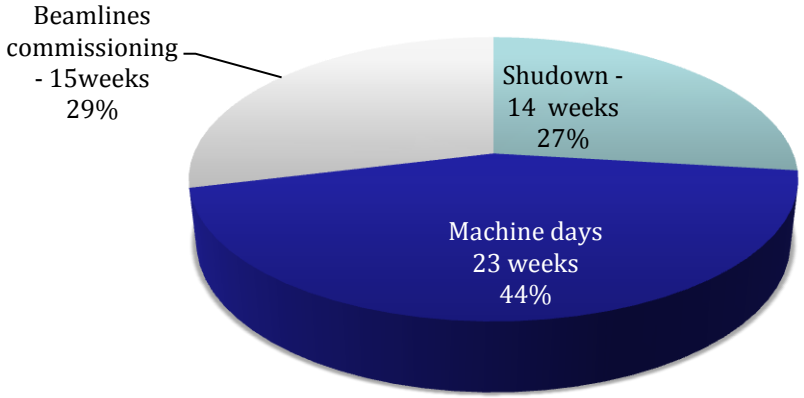
Optics design by S.C. Leemann - MAXIV

OPERATION CALENDAR

2017			
Week			Operation mode
1	2017-01-02	2017-01-08	Shutdown
2	2017-01-09	2017-01-15	Shutdown
3	2017-01-16	2017-01-22	Machine dedicated time/start up
4	2017-01-23	2017-01-29	Machine dedicated time
5	2017-01-30	2017-02-05	Machine dedicated time
6	2017-02-06	2017-02-12	Machine dedicated time
7	2017-02-13	2017-02-19	Machine dedicated time
8	2017-02-20	2017-02-26	Machine dedicated time
9	2017-02-27	2017-03-05	Machine dedicated time
10	2017-03-06	2017-03-12	Machine dedicated time
11	2017-03-13	2017-03-19	Machine dedicated time
12	2017-03-20	2017-03-26	Machine dedicated time
13	2017-03-27	2017-04-02	Beamline commissioning
14	2017-04-03	2017-04-09	Beamline commissioning
15	2017-04-10	2017-04-16	Beamline commissioning
16	2017-04-17	2017-04-23	Beamline commissioning
17	2017-04-24	2017-04-30	Beamline commissioning
18	2017-05-01	2017-05-07	Beamline commissioning
19	2017-05-08	2017-05-14	Shutdown
20	2017-05-15	2017-05-21	Shutdown
21	2017-05-22	2017-05-28	Machine dedicated time
22	2017-05-29	2017-06-04	Beamline commissioning
23	2017-06-05	2017-06-11	Beamline commissioning
24	2017-06-12	2017-06-18	Shutdown
25	2017-06-19	2017-06-25	Beamline commissioning
26	2017-06-26	2017-07-02	Beamline commissioning
27	2017-07-03	2017-07-09	Beamline commissioning
28	2017-07-10	2017-07-16	Beamline commissioning
29	2017-07-17	2017-07-23	Beamline commissioning
30	2017-07-24	2017-07-30	Shutdown
31	2017-07-31	2017-08-06	Shutdown
32	2017-08-07	2017-08-13	Shutdown
33	2017-08-14	2017-08-20	Shutdown
34	2017-08-21	2017-08-27	Shutdown
35	2017-08-28	2017-09-03	Machine dedicated time/start up
36	2017-09-04	2017-09-10	Machine dedicated time
37	2017-09-11	2017-09-17	Beamline commissioning
38	2017-09-18	2017-09-24	Beamline commissioning
39	2017-09-25	2017-10-01	Beamline commissioning
40	2017-10-02	2017-10-08	Beamline commissioning
41	2017-10-09	2017-10-15	Beamline commissioning
42	2017-10-16	2017-10-22	Beamline commissioning
43	2017-10-23	2017-10-29	Shutdown
44	2017-10-30	2017-11-05	Machine dedicated time
45	2017-11-06	2017-11-12	Beamline commissioning
46	2017-11-13	2017-11-19	Beamline commissioning
47	2017-11-20	2017-11-26	Beamline commissioning
48	2017-11-27	2017-12-03	Beamline commissioning
49	2017-12-04	2017-12-10	Beamline commissioning
50	2017-12-11	2017-12-17	Beamline commissioning
51	2017-12-18	2017-12-24	Shutdown
52	2017-12-25	2017-12-31	Shutdown

OPERATION working hours:
40 h/ week (5 days / 8h)

Forseen operation in 2017

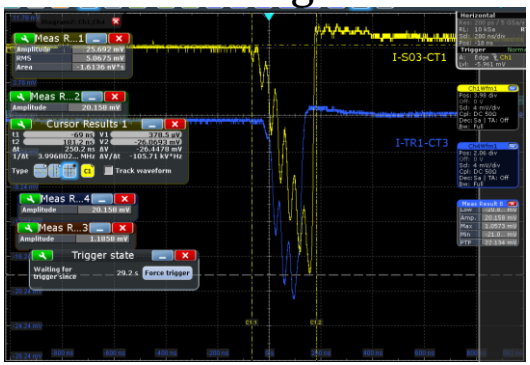


920 h for machine studies
with high current up to 400 mA
600 h for beamlines (low current <100mA)
~6000 h of beam in the storage ring
in decay mode – vacuum cleaning

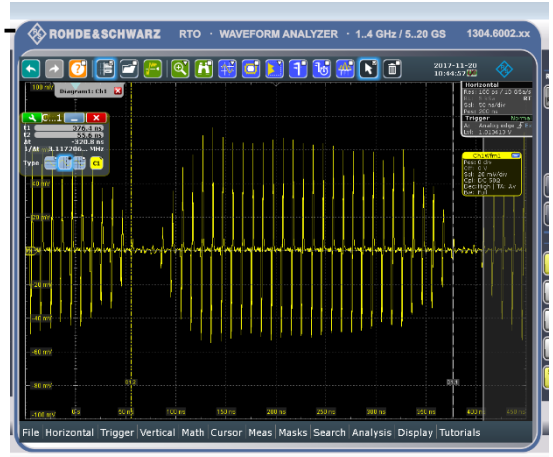
INJECTION & RAMPING

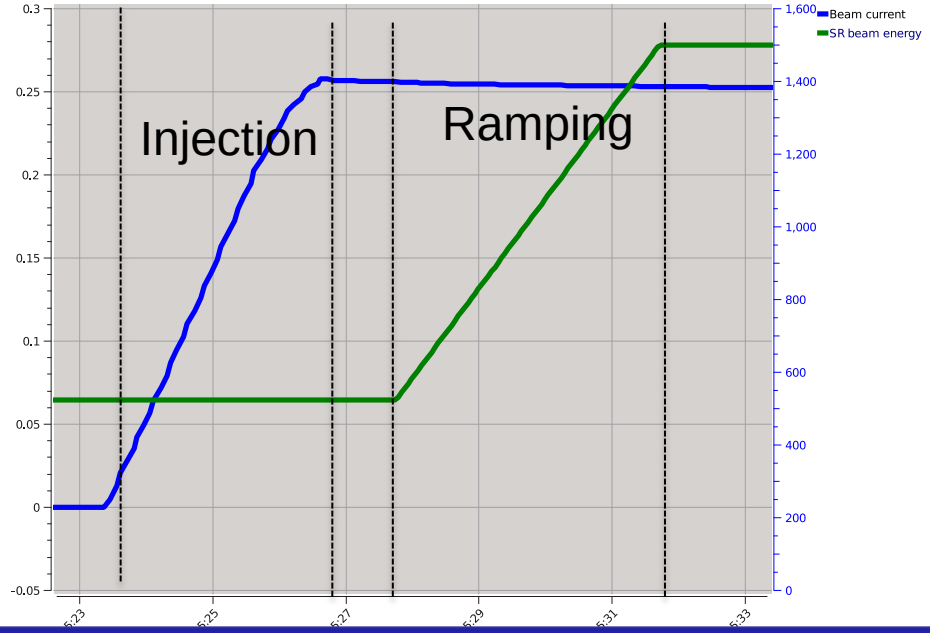
Injection at the energy of 535 MeV with the repetition rate of 1 Hz. The injection of 200 mA can be done in 140 s and ramping - in 238s. Injection efficiency – 30%.

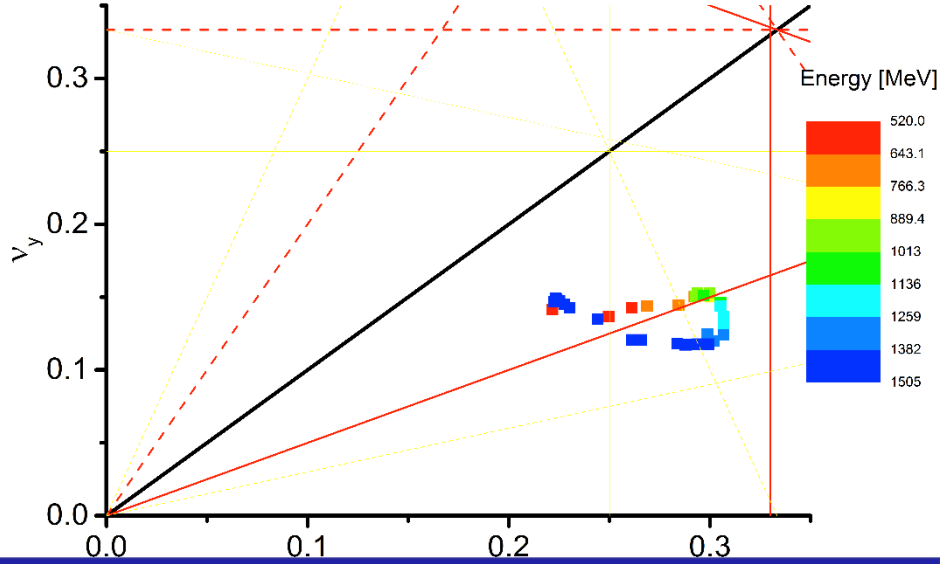
Bunch train length ~180 ns in the transfer line.



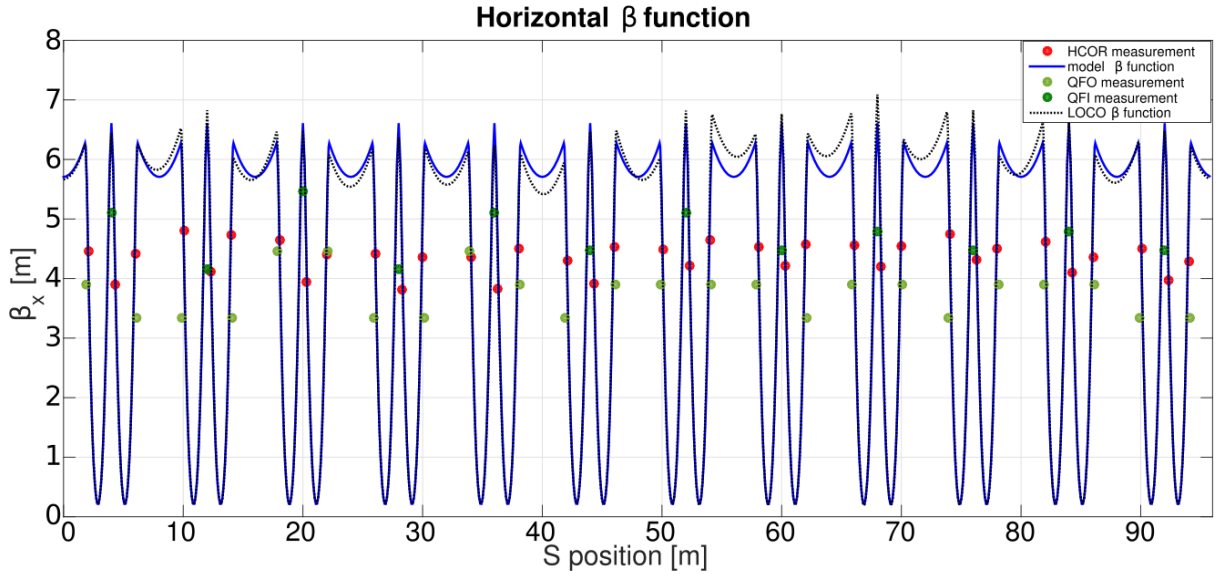
Filling pattern - 2bucket gap

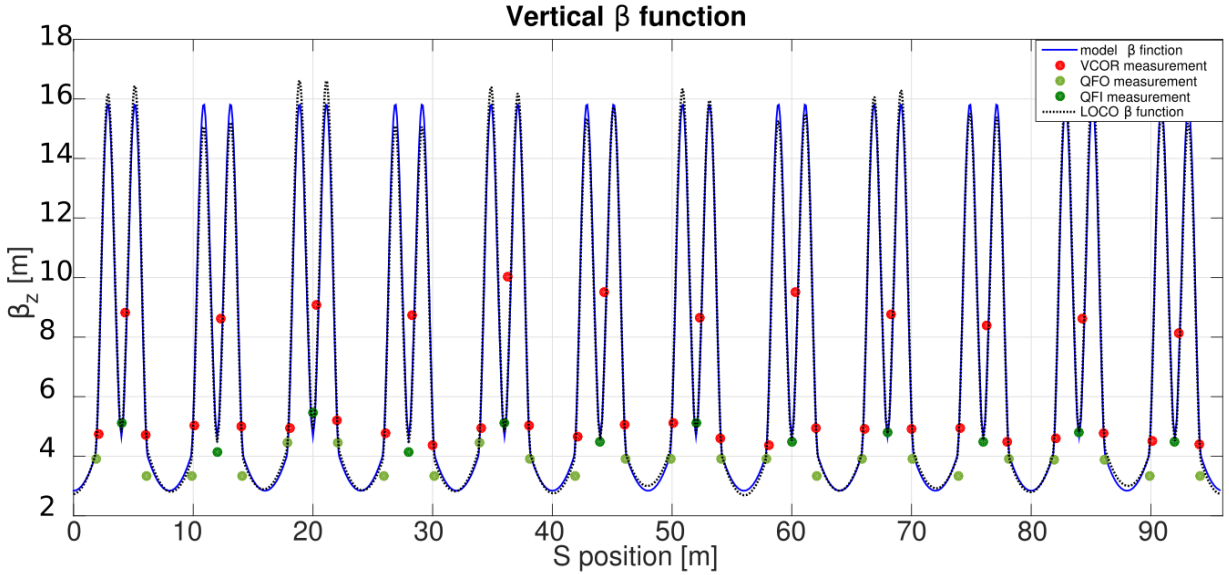






BETA FUNCTIONS





Quadrupole scan

$$\beta_{x,y} = \pm 4\pi \frac{\Delta Q_{x,y}}{\Delta k}.$$

ORM method

$$\beta_{x,y} = 2 \cdot \tan(\pi Q_{x,y}) \cdot \frac{\Delta x_{CM}}{\Delta \theta}$$

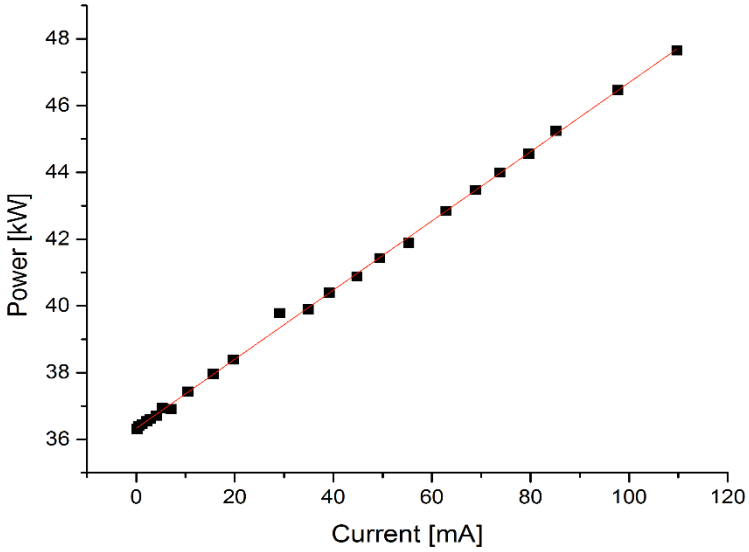
LOCO

$$\chi^2 = \sum_{i,j} \frac{\left(R_{i,j}^{meas} - R_{i,j}^{model}(\Delta k)\right)^2}{\sigma_i^2}$$

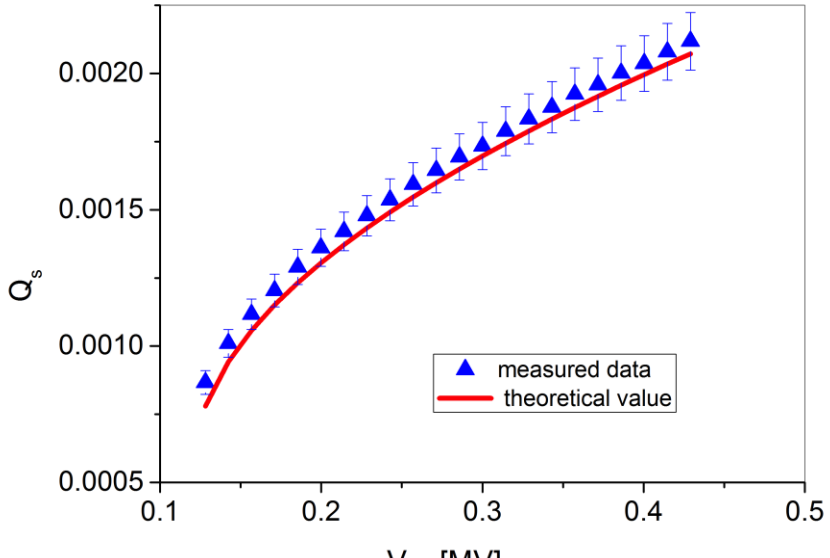
Method	Hor. beating	Vert. beating
QUAD	26.84%	33.52%
ORM	13.14%	23.49%
LOCO	16.45%	11.73%

The LOCO studies has revealed that the quad strength errors are up to 0.8 % for DBA2. The shunting of the magnets is planned.

SYNCHROTRON TUNE



Synchrotron tune vs. total RF voltage.

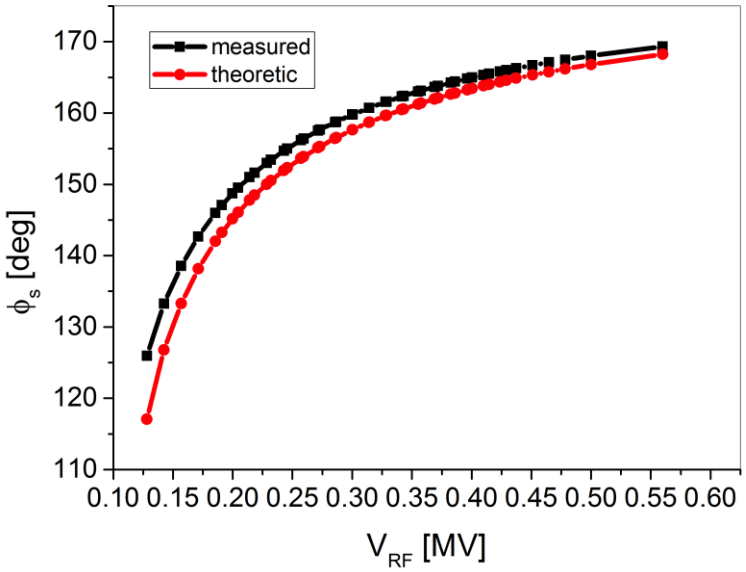


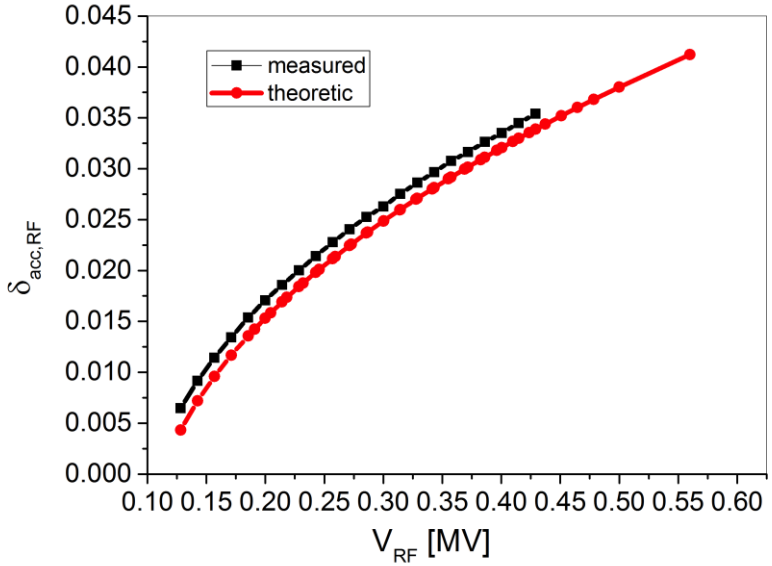
$$P_{forw} - P_{refl} = P_{cav} + \frac{IU_0}{e}$$

$$Q_s^2 = \frac{\alpha_c h}{2\pi E}\sqrt{e^2 V_{RF}^2 - U_0^2}$$

	Designed	Measured
U_o [keV/turn]	114.1	103.7 (12.3)
E [GeV]	1.5	1.45 ()
P_{cav} [kW]	49	39 (1)
Φ_s [deg]	168	167.4

RF ACCEPTANCE

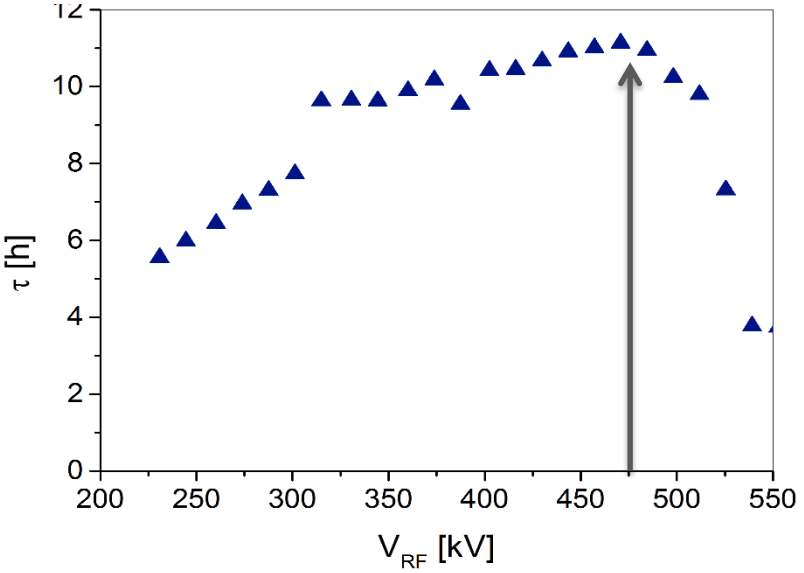




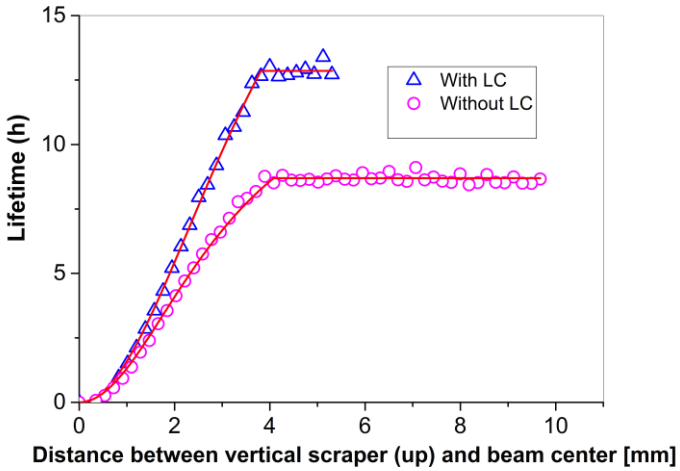
Synchronous phase 167.4° ± 2.7°

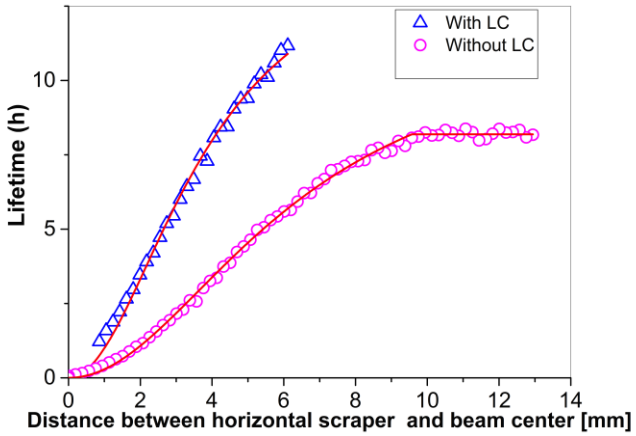
$$\delta_{acc,RF} \approx \frac{2Q_s}{h\alpha_c}\sqrt{1+(\phi_s-\frac{\pi}{2})\tan(\phi_s)}$$

RF acceptance 3.7% ± 0.3%
V_{RF}=480kV



LIFETIME





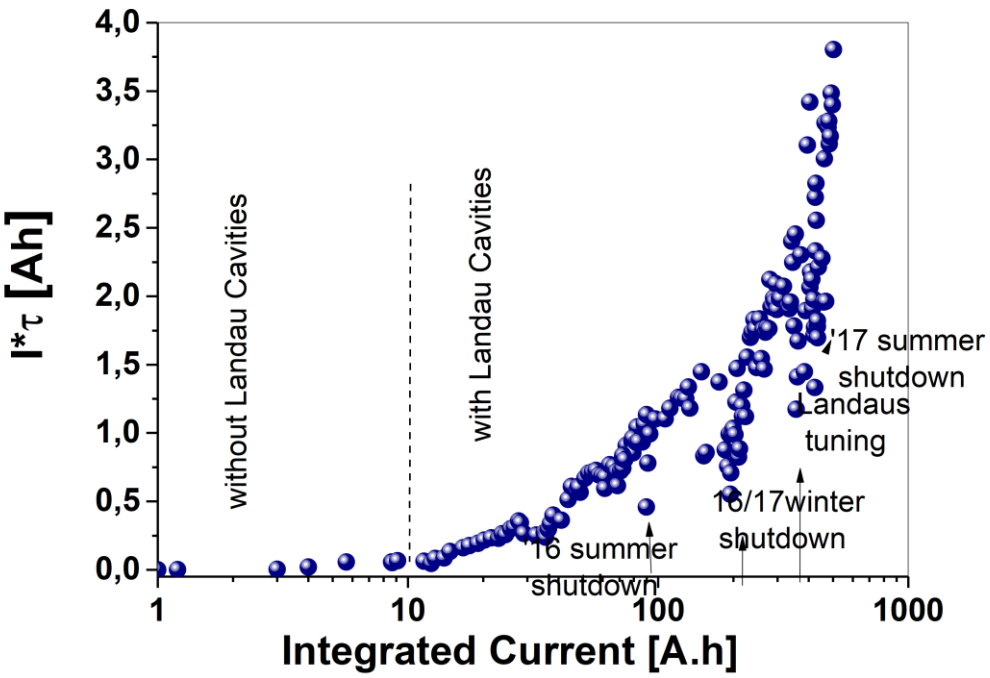
	without LC	with LC
Elastic scattering $\tau_{elastic}$	22.24	23.66 h
Inelastic scattering $\tau_{inelastic}$	37.45 h	43.57 h
Touschek lifetime $\tau_{Touschek}$	21. 13 h	68.81 h
Total lifetime τ_{tot}	8.41 h	12.54 h

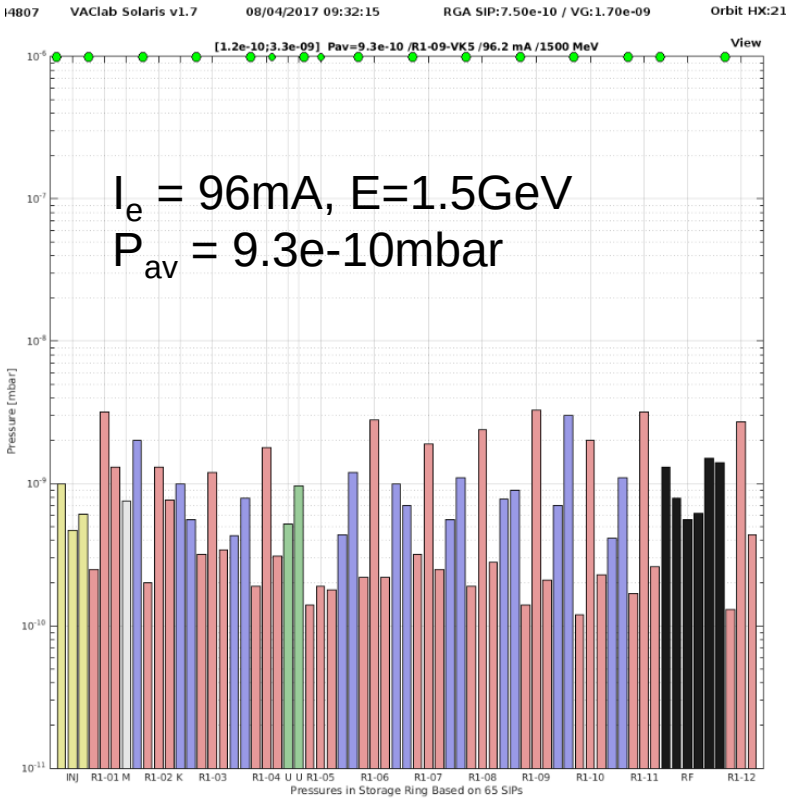
Physical acceptance for Solaris storage ring:
$A_x(\delta)$= 15.68 mm·mrad;
$A_y(\delta)$= 3.77 mm·mrad

CURRENT

The bam lifetime is still increasing with the accumulated beam dose.

The average pressure in the storage ring with 250 mA of a stored current at 1.5 GeV is $2.2 \cdot 10^{-9}$ mbar.





Maximum injected current over 600 mA.
Maximum current at full energy over 400 mA.

ACHIEVED SR PARAMETERS

Parameter	Designed	Measured
Electron energy	1.5 GeV	1.45 ±0.5 GeV
Max. current	500 mA	409 mA
Number of circulating bunches	32	30
Natural bunch length σ_z /w. Landau Cavities	14.2 /60 mm	-
Natural emittance (bare lattice)	5.982 nmrad	-
Coupling	1 %	-
Energy spread (bare lattice)	0.000745	-
Tunes ν_x, ν_y	11.22, 3.15	11.22, 3.15
Natural chromaticities ξ_x, ξ_y	-22.96, -17.14	-
Corrected chromaticities ξ_x, ξ_y	+2,+2 ; +1, +1	+1.4, +1.6;+0.9,+0.9
Momentum compaction	3.055×10^{-3}	-
Energy loss/turn	114.1 keV	103.7 ±12.3 keV
Momentum acceptance	4%	3.7± (0.3)%
Synchronous phase	168^o	$167.4^o \pm 2.7^o$
Synchrotron tune	0.00239	0.00228
Physical acceptance h/v	18 /4 mmrad	15.68/3.77 mmrad
Total lifetime	13 h	8 h

NEXT GOALS

Linac and Transfer Line

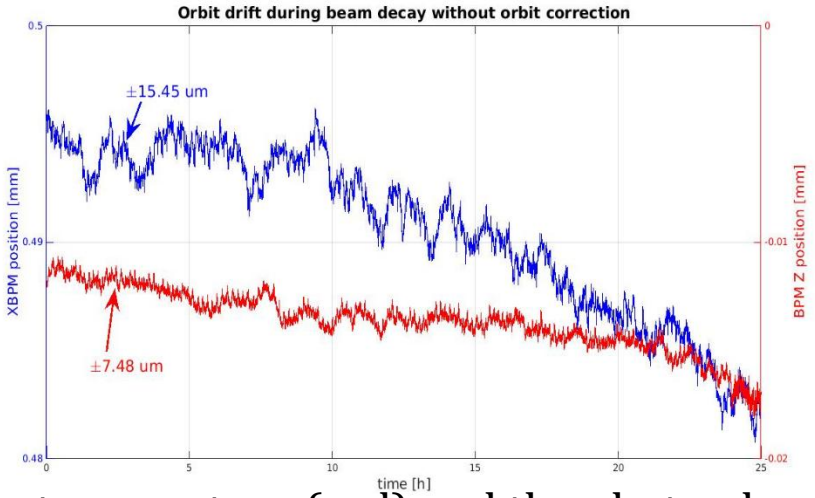
- ✓ Emittance and energy spread measurements
- ✓ Optics adjustments for injection optimisation
- ✓ **Chopper commissioning [ongoing]**
- ✓ Magnets settings optimisation at nominal energy after full conditioning and SLED tuning

Storage Ring

- ✓ Shunting the magnets based on LOCO
- ✓ Beam based alignment (BBA)
- ✓ Beam stability studies
- ✓ Beam dynamics with insertion devices studies
- ✓ Nonlinear beam dynamics studies with pinger
- ✓ FOFB impelmentation – fast correctors procured, PS specification under preapration
- ✓ Diagnostic beamlimes installation and emittance measurements
- ✓ Instabilities studies

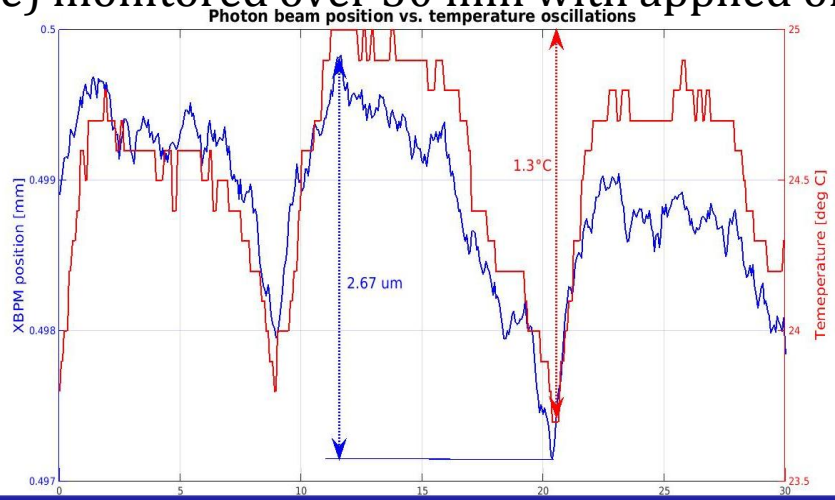
BEAM STABILITY

The vertical position drift of electron (red) and photon (blue) beam monitored over 25h without orbit correction.



Temperature oscillations in the range of 1.5-2.0 ^{o}C in the storage ring have impact on beam stabilty.

The temperature (red) and the photon beam oscillations (blue) monitored over 30 min with applied orbit correction.

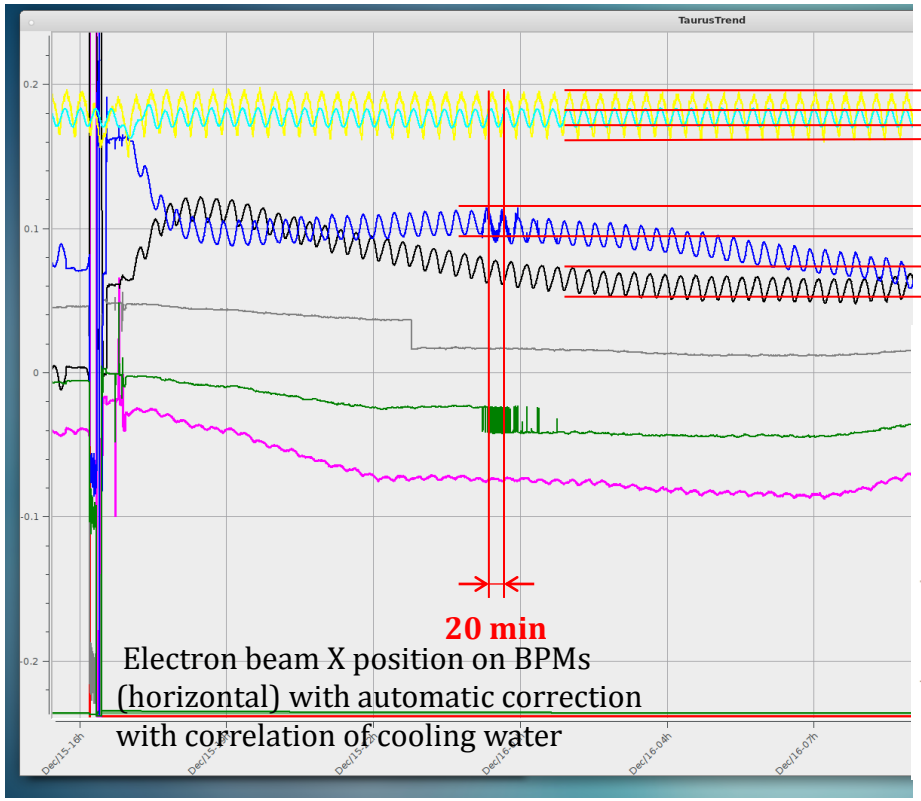


Beam drift in Storage Ring

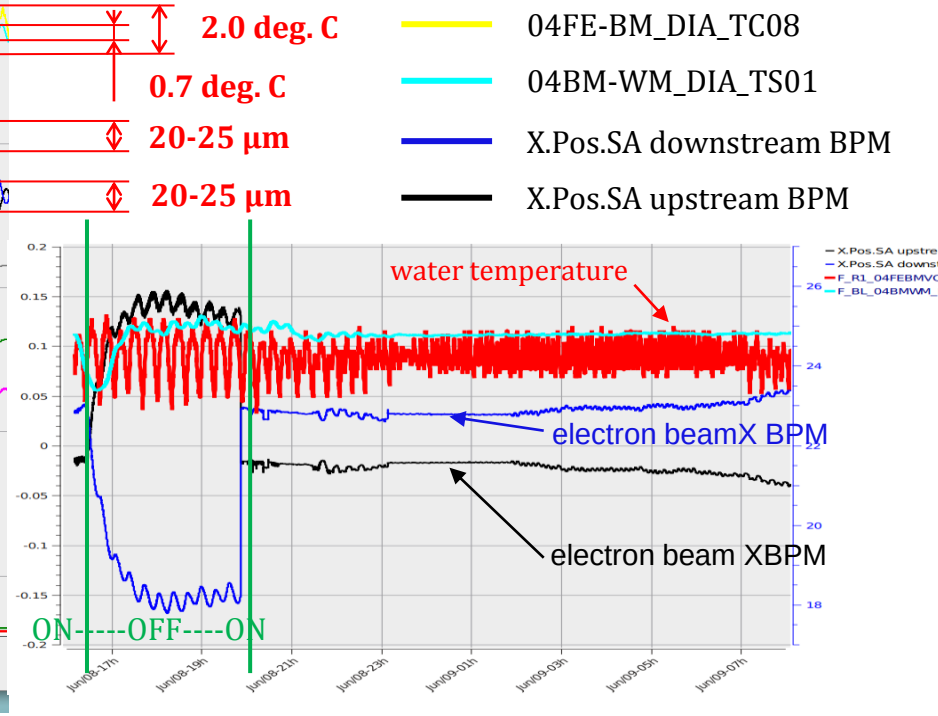
By the end of 2016, beam diagnostics reported on the observed electron beam oscillations in the Storage Ring.

1. Amplitude of vibration
   a) with no automatic correction: **20-25 µm**
   b) with automatic correction: **8-15 µm**
2. Oscillation period: **20 min**
3. Place of measurement: **BPMs &XBPMs**

The direct cause of the oscillation of the electron beam and the photon beam in the Storage Ring is the oscillation of the cooling water temperature in main backbone.

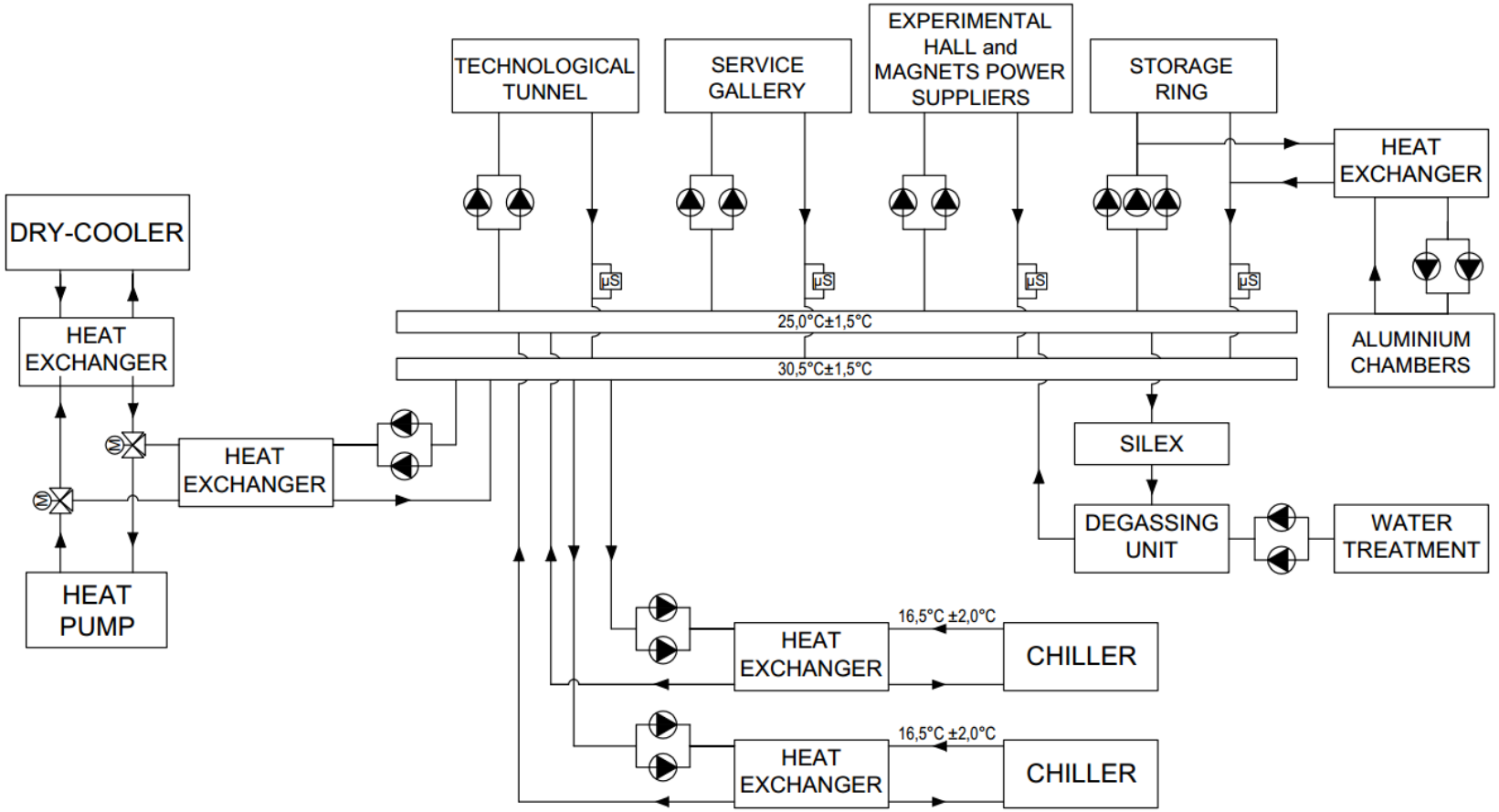


Electron beam X position on BPMs (horizontal) with automatic correction with correlation of cooling water



Time period: 16 h, correction ON-OFF-ON

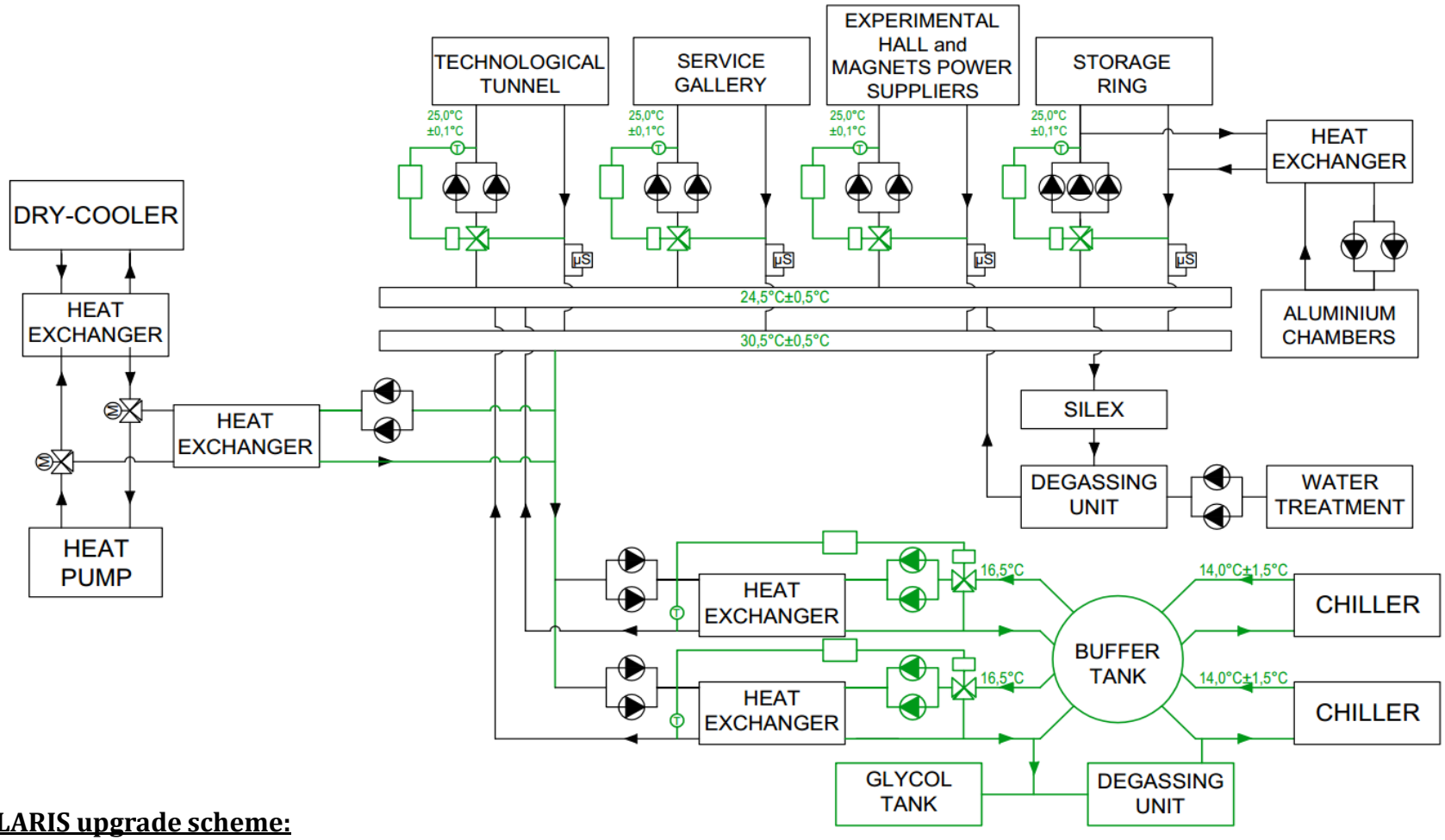
Upgrade of the scheme



SOLARIS current scheme:

1. Stability of the cooling source: +/- 2.0 K
2. Temperature control accuracy: +/- 1.5 K

Upgrade of the scheme



SOLARIS upgrade scheme:

1. Stable cooling source: +/- 0.5 K – realized by additional glycol buffer tank (~6000 l) and three-way valves on the glycol side
2. Temperature control accuracy: +/- 0.1 K – realized by three-way valves on the demi water side
3. Industry automation

FAILURES OF THE RF EQUIPMENT

Modulators:

- First broken IGBT in the high voltage switch unit. Equipment after warranty.

100MHz cavities

- Leakage up to 1.0e-7 mbar*l/s at ceramic of pick-ups (already 4 pieces).

New designed pick-up's without ceramics have been delivered under warranty.

Rhode & Schwarz signal generator SMA100A (Master Oscillator for linac)

- Synchronization error on 10MHz reference, repaired under warranty -> OCXO oven problem

Overheating of 50W 20dB RF attenuators from Landau cavities pick-up

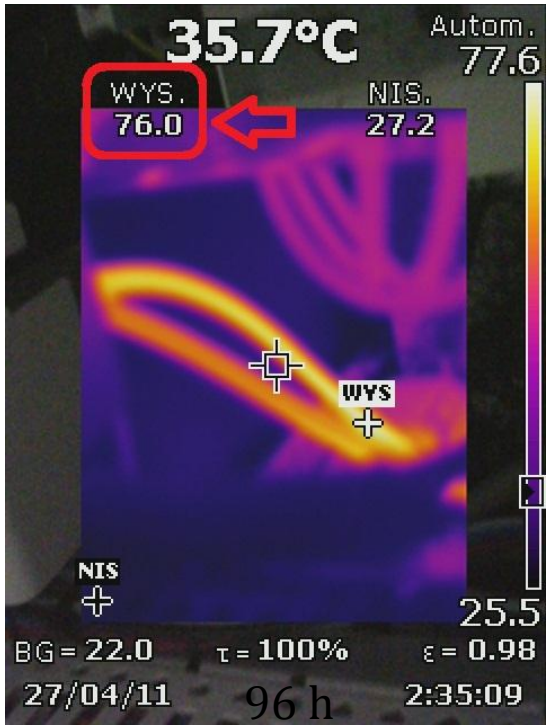
- Not detectable by LLRF because of 450MHz low pass filter in series
- Expected few watts, value from 100MHz - 3GHz spectrum measurements during commissioning at certain Landau tuning position
- Investigation on-going, >150mA beam current needed

FAILURES OF STORAGE RING PS

Breakdown of PS switch

Downtime: 96 h

PS overheating due to water flow limitation



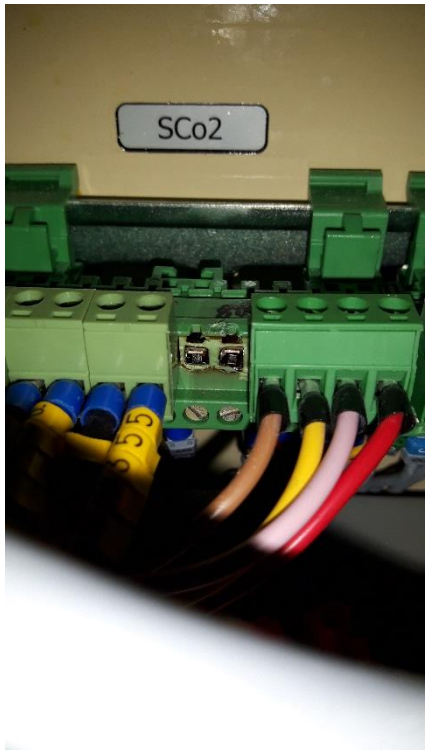
Failure of 5V inner power supply for analog part of control board

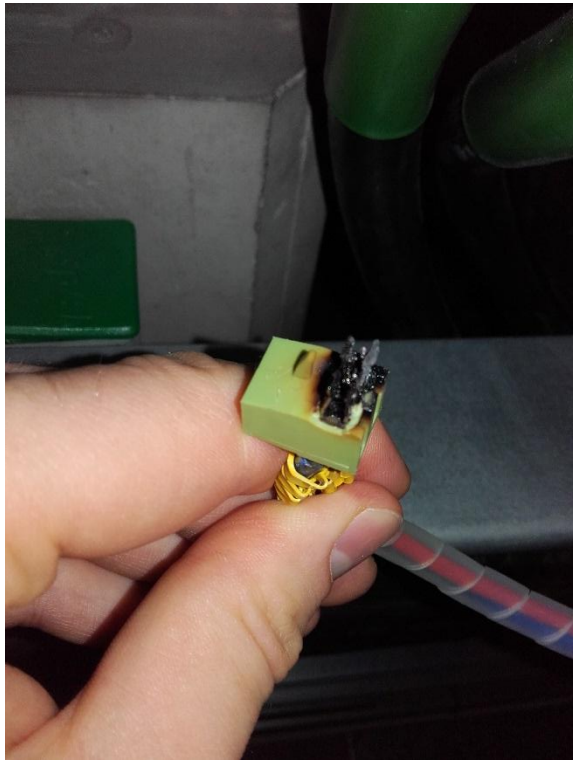
28 h

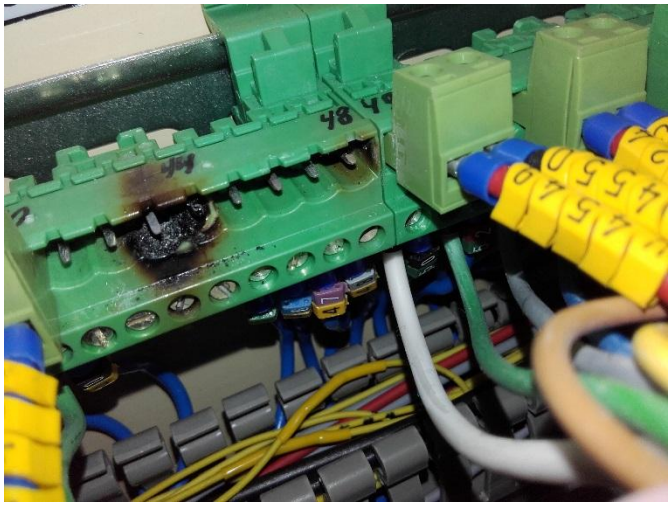
In total 220 h of downtime due to main PS problems

Corrector magnets connetors failures

Problems with connectors for corrector magnets







Downtime: 6 h

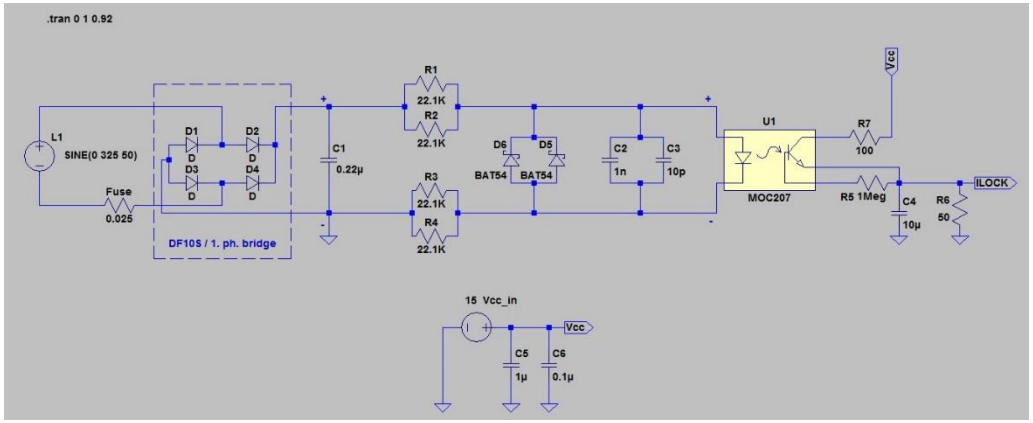
Actions: - We are going to replace the connectors with solid soldered cables during winter shutdown.

Most serious failures

Pinger failure

Actions:

- After Solaris' diagnose BINP provided us new phase detectors and replacement for other burned electronics elements;
- We are working on new improved phase detector for the Pinger;
- IGBT section (most sensitive part of the kicker and pinger) was investigated after the failure and as for now everything looks good.



Beamlines status

XAS/PEEM Beamline commissioning and operation

First light at the beamline components 11th April 2017.
Beamline commissioning will take approximately up to May 2018
Phase 1: Alignment of main beamline optics to obtain focused beam at exit slits, degassing of optics
Phase 2: Fine tuning of the main beamline optics, energy calibration, test with XAS
Phase 3: Friendly User's experiments at XAS, refocusing optics alignment, test with PEEM
After successful preliminary experiments the beamline can be opened to Users (05.2018)

UARPES Beamline

April 2016 - start of commissioning,
Sept.-Nov. 2016 carbon deposits found on optical elements. Fluorocarbons found in the MONO and MIRRORs chambers

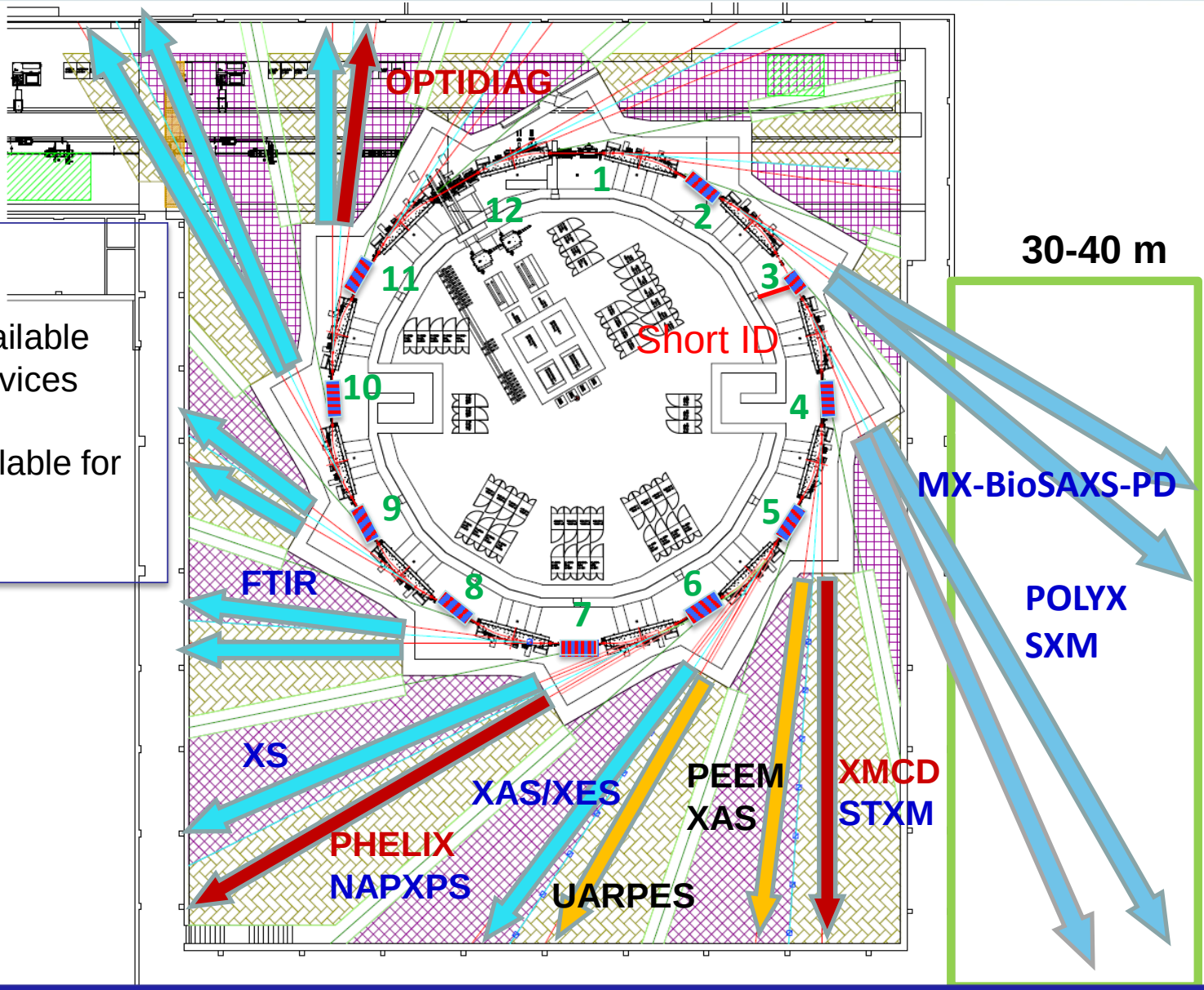
Jan- Jul. 2017 ELETTRA accepts warranty claims and carry out further diagnistics. Optical elements are recoated with Au layers on Cr adhesion layer.
Aug.-Nov. 2017 The beamline mechanisms are redelivered and installed. The beamline is precisely realigned The sections MIRROR1, MIRROR2, MIRROR3, and MONO are baked and the UHV restored.
Mid of Nov. 2017 – Commissioning of UARPES beamline restarted

FUTURE BEAMLINES

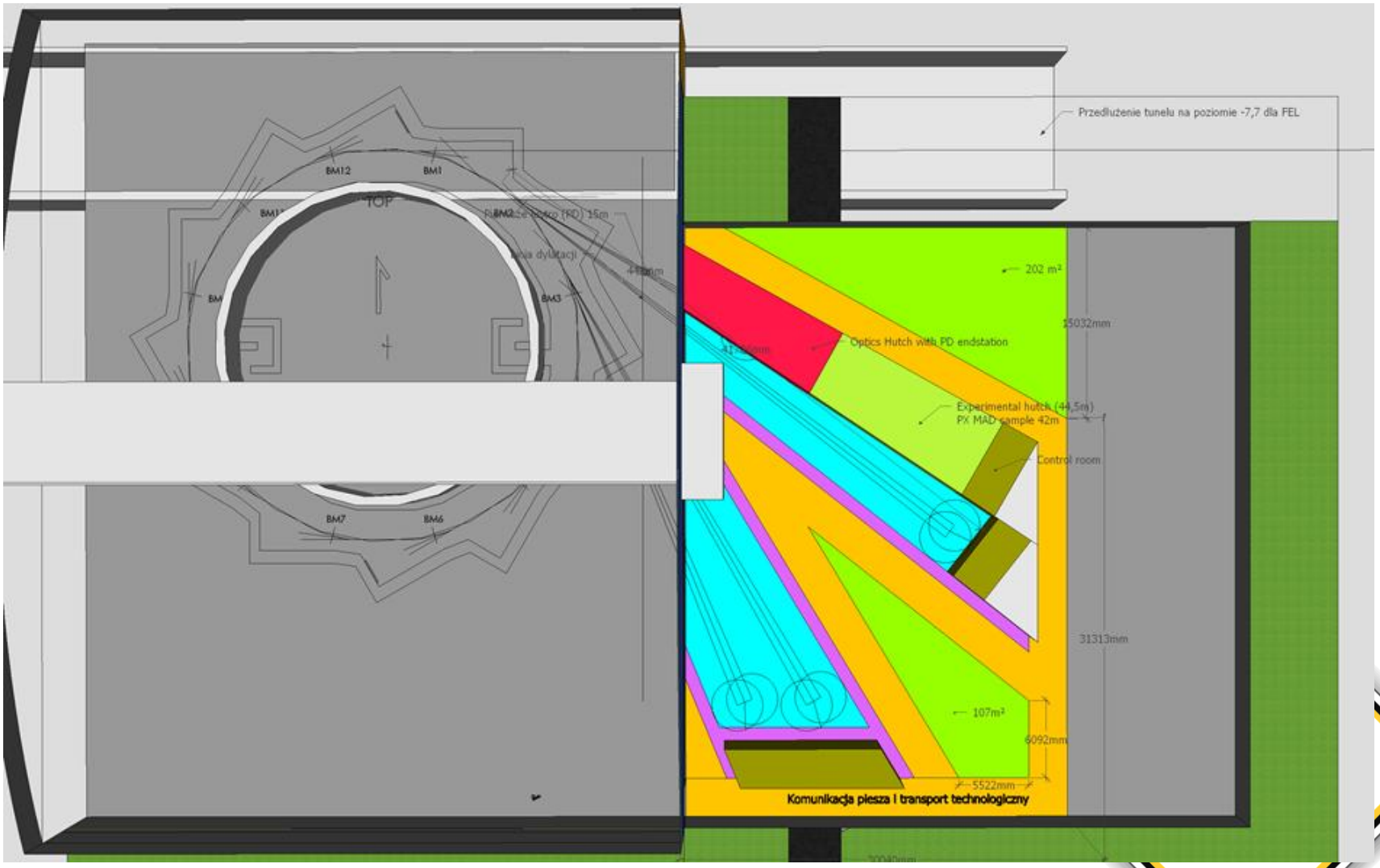
Future Beamlines:

8 straight sections available for 2.6 m insertion devices

1 straight section available for short (1.5 m) ID



BUILDING EXPANSION



SUMMARY

- A good performance of the Solaris stoarge ring has been achieved.
- **Tuning of the Landau** cavities **improved** the **Touschek lifetime** by factor of 3 and cured some instabilities.
- **Temperature oscillations** in the range of 1.5°C in the storage ring have **impact** on **beam stability and the improvement of the main cooling system is under development**.
- The UARPES and XAS/PEEM beamlines commissioning is ongoing.
- Forseen **user operation** will start in **September 2018**
- Next two **beamlines PHELIX and XMCD** are funded and will be installed by **mid of 2019**
- **Future operation**
  - Preparation for 24/7 operation - 3 shifts; compensation for weekends, nights and on call duties – have to be sorted within Jagiellonian University
  - Operators -10 persons -> existing personnel plus hiring new people (Acc. Phys.);
  - Key Spare parts – planning the budget for next 2-3 years
  - Tools and procedures for reliable operation

Thank you for the attention!