JAGIELLONIAN UNIVERSITY
IN KRAKOW

SOLARIS
NATIONAL SYNCHROTRON
RADIATION CENTRE

JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

Solaris Status

Adriana Wawrzyniak

On behalf of Machine Group

National Synchrotron Radiation Center SOLARIS

Kraków, 27.11.18

OUTLINE

Outline

- Introduction
- Operation in 2018
- Machine failures
- Machine ugrades & improvements
- Summary

SOLARIS OVERVIEW

600 MeV Linac with RF Thermionic Gun
1.5 GeV Storage Ring
2 operating beamlines

Parameter	Designed	Measured
Electron energy	1.5 GeV	1.45 ±0.5 GeV
Max. current	500 mA	500 mA/ operation @280mA
Number of circulating bunches	32	30-32
Natural bunch length σ_z /w. Landau Cavities	14.2 /60 mm	-
Natural emittance (bare lattice)	5.982 nmrad	8.05 nmrad (±30%)
Coupling	1 %	0.86%
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°	167.4° ± 2.7°
Synchrotron tune	0.00239	0.00228
Physical acceptance h/v	18 /4 mmrad	15.68/3.77 mmrad
Total lifetime	13 h	8 h

PLANS FOR NEXT BEAMLINES

Cryo EM

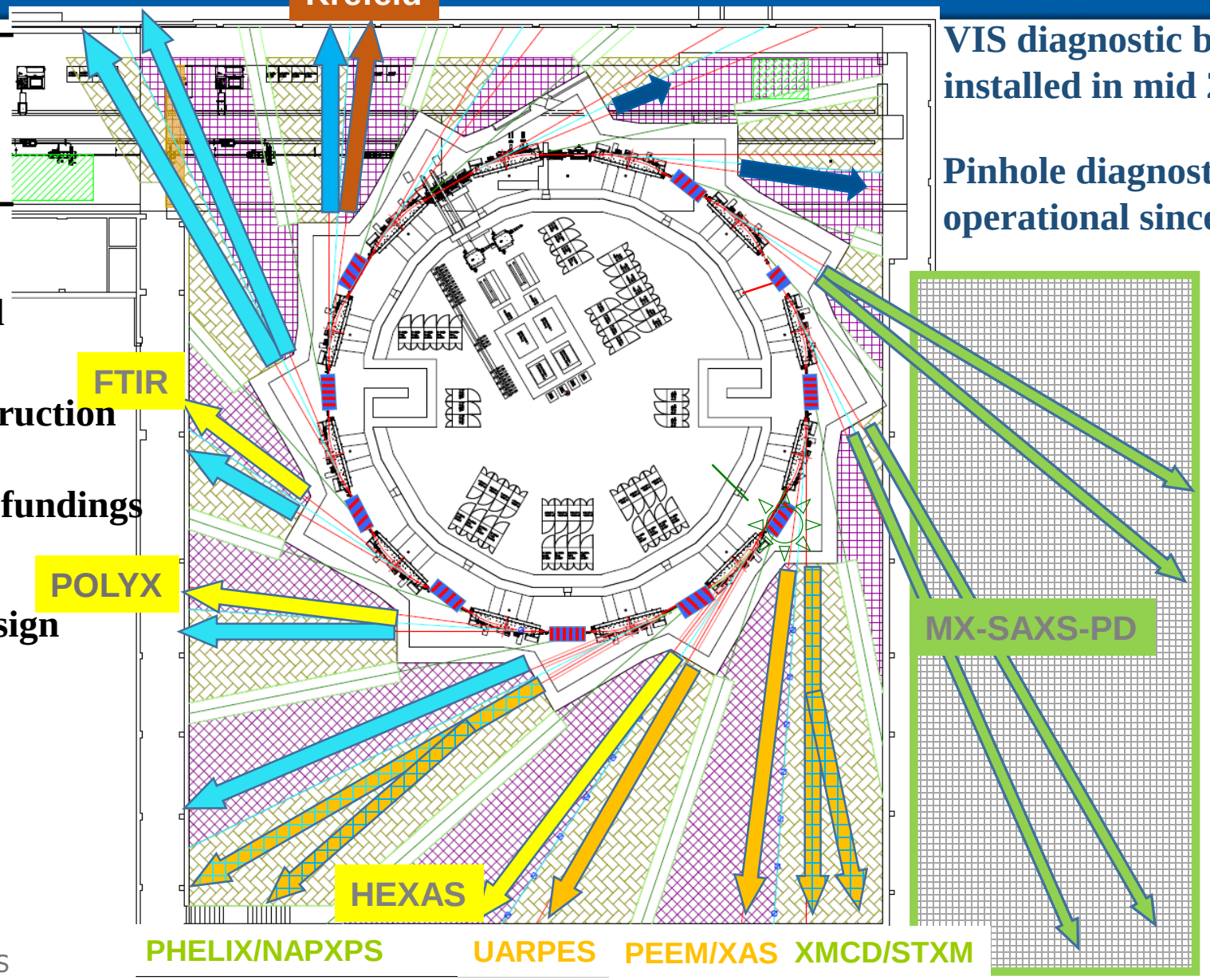
Funded

2018 Operational

2019 Under construction

2020 Applied for fundings

2022 Funded, design just stared



VIS diagnostic beamline to be installed in mid 2019

Pinhole diagnostic beamline operational since september 2018

SOLARIS OPERATION

Operation Calendar 2018/2019

FIRST USERS on October, 1st

Aug 2018			Sep 2018			Oct 2018			Nov 2018			Dec 2018			Jan 2019			Feb 2019			Mar 2019			Apr 2019			May 2019			Jun 2019			Jul 2019		Aug 2019	
######	s	s	Sat 01			######	M		Thu 01			Sat 01	B		Tue 01	s	s	Fri 01	M		Fri 01	B	B	######	M		######	s	s	Sat 01			######	M	Thu 01	s s
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Sun 05	s	s	######	C	C	Fri 05	B	B	######	M		######	B	B	Sat 05	s	s	Tue 05	C	C	Tue 05	B	B	Fri 05	B	B	Sun 05	s	s	######	B	B				
######	s	s	Thu 06	C	C	Sat 06			Tue 06	C	C	Thu 06	B	B	Sun 06	s	s	######	C	C	######	B	B	Sat 06			######	s	s	Thu 06	B	B				
Tue 07	s	s	Fri 07	B	B	Sun 07			######	B	B	Fri 07	B	B	######	s	s	Thu 07	B	B	Thu 07	B	B	Sun 07			Tue 07	s	s	Fri 07	B	B				
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Thu 09	s	s	Sun 09			Tue 09	B	B	Fri 09	B	B	Sun 09			######	s	s	Sat 09			Sat 09			Tue 09	B	B	Thu 09	s	s	Sun 09						
Fri 10	s	s	######	M		######	B	B	Sat 10			######	M		Thu 10	s	s	Sun 10			Sun 10			######	B	B	Fri 10	s	s	######	M					
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Sun 12	s	s	######	B	B	Fri 12	B	B	######	M		######	B	B	Sat 12	s	s	Tue 12	B	B	Tue 12	s	s	Fri 12	B	B	Sun 12	s	s	######	B	B				
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Tue 14	s	s	Fri 14	B	B	Sun 14			######	B	B	Fri 14	B	B	######	s	s	Thu 14	B	B	Thu 14	s	s	Sun 14			Tue 14	M		Fri 14	B	B				
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Sun 26	s	s	######	B	B	Fri 26	s	s	######	B	B	######	s	s	Sat 26			Tue 26	B	B	Tue 26	C	C	Fri 26	B	B	Sun 26			######	B	B				
######	O		Thu 27	B	B	Sat 27	s	s	Tue 27	B	B	Thu 27	s	s	Sun 27			######	B	B	######	B	B	Sat 27			######	M		Thu 27	B	B				
Tue 28	O		Fri 28	B	B	Sun 28	s	s	######	s	B	Fri 28	s	s	######	M		Thu 28	B	B	Thu 28	B	B	Sun 28			Tue 28	B	B	Fri 28	B	B				
######	O		Sat 29			######	O		Thu 29	B	B	Sat 29	s	s	Tue 29	M					Fri 29	B	B	######	s	s	######	B	B	Sat 29						
Thu 30	O		Sun 30			Tue 30	M		Fri 30	B	B	Sun 30	s	s	######	M					Sat 30			Tue 30	s	s	Thu 30	B	B	Sun 30						
Fri 31	O					######	M					######	s	s	Thu 31	M					Sun 31						Fri 31	B	B							

SOLARIS OPERATION

Shifts organisation

- 2 Shifts from Tue to Fri
- 2 operators on shift
- 1st shift 8:00 -16:00; 2nd shift 14:00-22:00 by September
- From October shifts 7:00-15:00; 14:00-22:00
- 3 Injection per day 7:00; 14:00; 21:00
- On call duties and extra hours during night shifts and Saturdays extra payed for operators and technical support

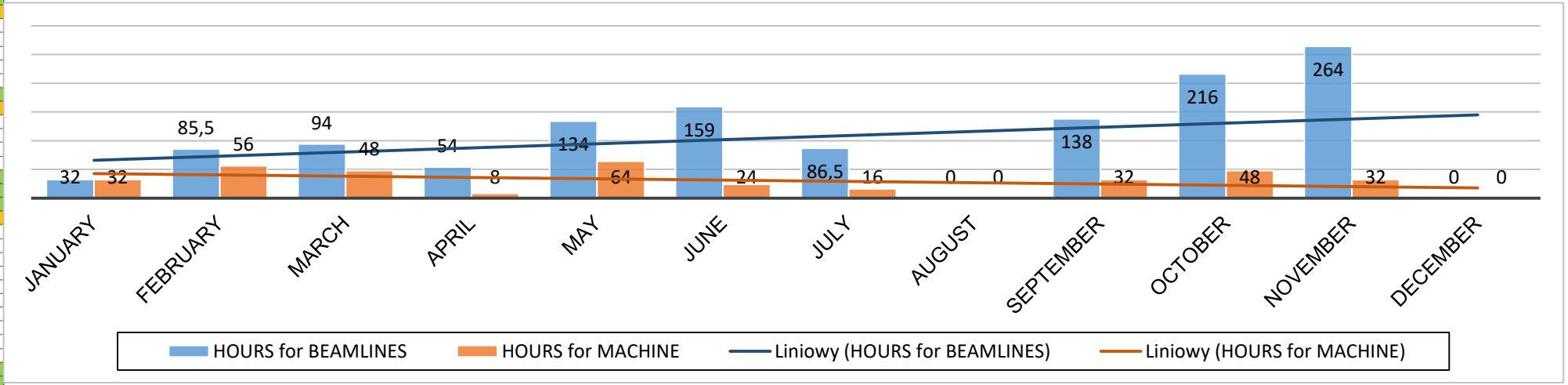
- 7 trained operators – operators are the machine and technical group members.
- Plan to increase the number of operators. Train beamline scientists (5 people)
- Increase employment in the machine group – open positions for Physicists, diagnostics spec., RF spec.; vacuum spec. and technician

SOLARIS OPERATION

Operation Calendar in 2018

2018			
Week			Operation mode
1	2018-01-01	2018-01-07	Shutdown
2	2018-01-08	2018-01-14	Shutdown
3	2018-01-15	2018-01-21	Shutdown
4	2018-01-22	2018-01-28	Machine dedicated time/start up
5	2018-01-29	2018-02-04	Beamline commissioning
6	2018-02-05	2018-02-11	Beamline commissioning
7	2018-02-12	2018-02-18	Beamline commissioning
8	2018-02-19	2018-02-25	Beamline commissioning
9	2018-02-26	2018-03-04	Beamline commissioning
10	2018-03-05	2018-03-11	Shutdown
11	2018-03-12	2018-03-18	Machine dedicated time
12	2018-03-19	2018-03-25	Beamline commissioning
13	2018-03-26	2018-04-01	Beamline commissioning
14	2018-04-02	2018-04-08	Beamline commissioning
15	2018-04-09	2018-04-15	Beamline commissioning
16	2018-04-16	2018-04-22	Shutdown
17	2018-04-23	2018-04-29	Shutdown
18	2018-04-30	2018-05-06	Shutdown
19	2018-05-07	2018-05-13	Machine dedicated time
20	2018-05-14	2018-05-20	Machine/ Beamline commissioning
21	2018-05-21	2018-05-27	Beamline commissioning /FUO
22	2018-05-28	2018-06-03	Beamline commissioning /FUO
23	2018-06-04	2018-06-10	Beamline commissioning /FUO
24	2018-06-11	2018-06-17	Beamline commissioning /FUO
25	2018-06-18	2018-06-24	Beamline commissioning /FUO
26	2018-06-25	2018-07-01	Beamline commissioning /FUO
27	2018-07-02	2018-07-08	Beamline commissioning /FUO
28	2018-07-09	2018-07-15	Beamline commissioning /FUO
29	2018-07-16	2018-07-22	Beamline commissioning /FUO
30	2018-07-23	2018-07-29	Shutdown
31	2018-07-30	2018-08-05	Shutdown
32	2018-08-06	2018-08-12	Shutdown
33	2018-08-13	2018-08-19	Shutdown
34	2018-08-20	2018-08-26	Shutdown
35	2018-08-27	2018-09-02	Machine dedicated time/start up
36	2018-09-03	2018-09-09	User operation
37	2018-09-10	2018-09-16	User operation
38	2018-09-17	2018-09-23	User operation
39	2018-09-24	2018-09-30	User operation
40	2018-10-01	2018-10-07	User operation
41	2018-10-08	2018-10-14	User operation
42	2018-10-15	2018-10-21	User operation
43	2018-10-22	2018-10-28	Shutdown
44	2018-10-29	2018-11-04	Machine dedicated time
45	2018-11-05	2018-11-11	User operation
46	2018-11-12	2018-11-18	User operation
47	2018-11-19	2018-11-25	User operation
48	2018-11-26	2018-12-02	User operation
49	2018-12-03	2018-12-09	User operation
50	2018-12-10	2018-12-16	User operation
51	2018-12-17	2018-12-23	Shutdown
52	2018-12-24	2018-12-30	Shutdown

OPERATION working hours



1503 h scheduled for BL by the end of 2018

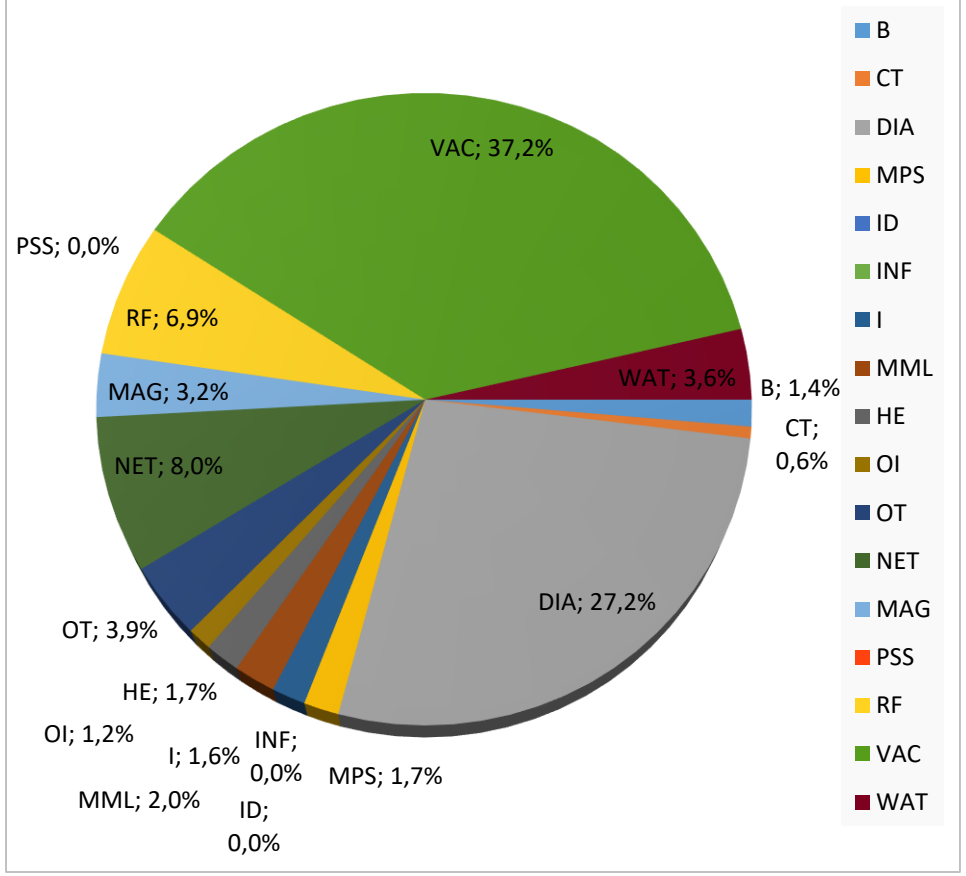
By today

	Scheduled	Used
TOTAL HOURS BL	1236	1118,3
TOTAL HOURS MC	360	359,7

2018	Availability[%]	MTBF[h]	MTTR [h]	Av I [mA]
October	97.2	19.1	0.9	250
November	99.6	73.3	0.3	262
2018	91.4	18.6	1.5	

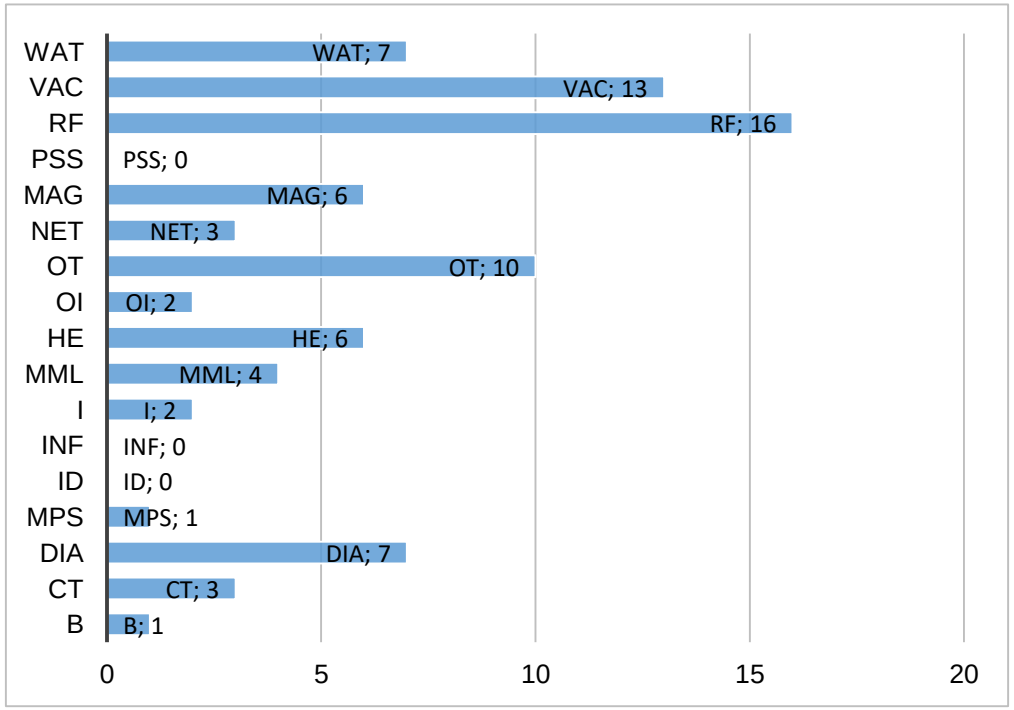
OPERATION STATISTICS

MACHINE FAILURES



Main failures

- ☹ Diagnostic trips due to libera suspension in March
- ☹ Vacuum trips due to malfunction of the VK2 March-April
- ☹ Correctors connection burn
- ☹ Semiinstrument PS –current drops during ramping [solved]
- ☹ Water interlocks
- ☹ RF – LLRF phase stabilization, plungers in LC



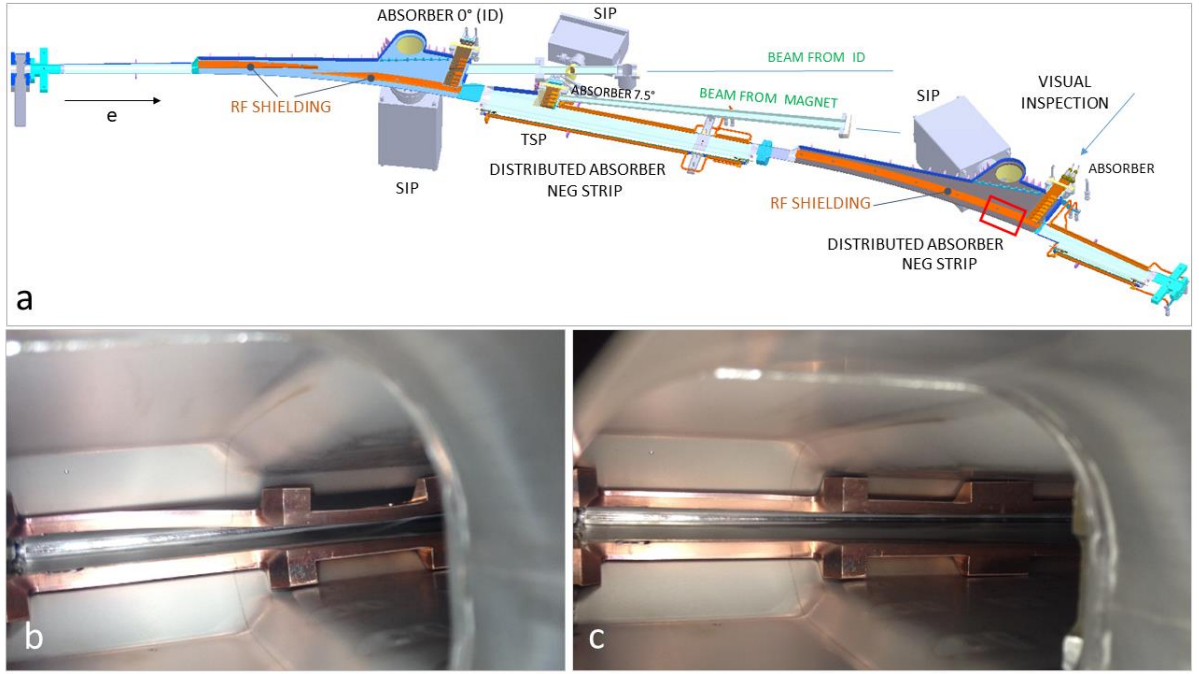
	Failure CODE List
B	Beamlines
CT	Controls
DIA	Diagnostics
MPS	MPS interlock
ID	Insertion Devices
INF	Infrastructure
I	Linac
MML	High Level Software (MML)
HE	Human error
OI	Orbit Interlock
OT	Others
NET	Network
MAG	Power Supplies
PSS	PSS (except BLs)
RF	Radio Frequency
VAC	Vacuum
WAT	Water interlocks

MACHINE FAILURES

Replacement of the dipole vacuum chamber in sector R1-02

- An abnormal value of heat was detected at the exit of the vacuum chamber by thermocouple connected in the vicinity of crotch absorber (CROD) and RF shielding.
- During visual inspection the shape of the RF shield was found out of the specification due to, as we think, a huge thermal load caused by synchrotron radiation.
- Since the vacuum performance of this chamber stood out clearly from the others vacuum chambers mounted in DBA's it was decided to replace this chamber with the spare one.
- Cause of problems: misteering of the electron beam

Why? Machine Protection System not sufficient enough! Not sufficient enough interlock system based on signals form BPM, thermocouples, pressure readings based on SIP's.

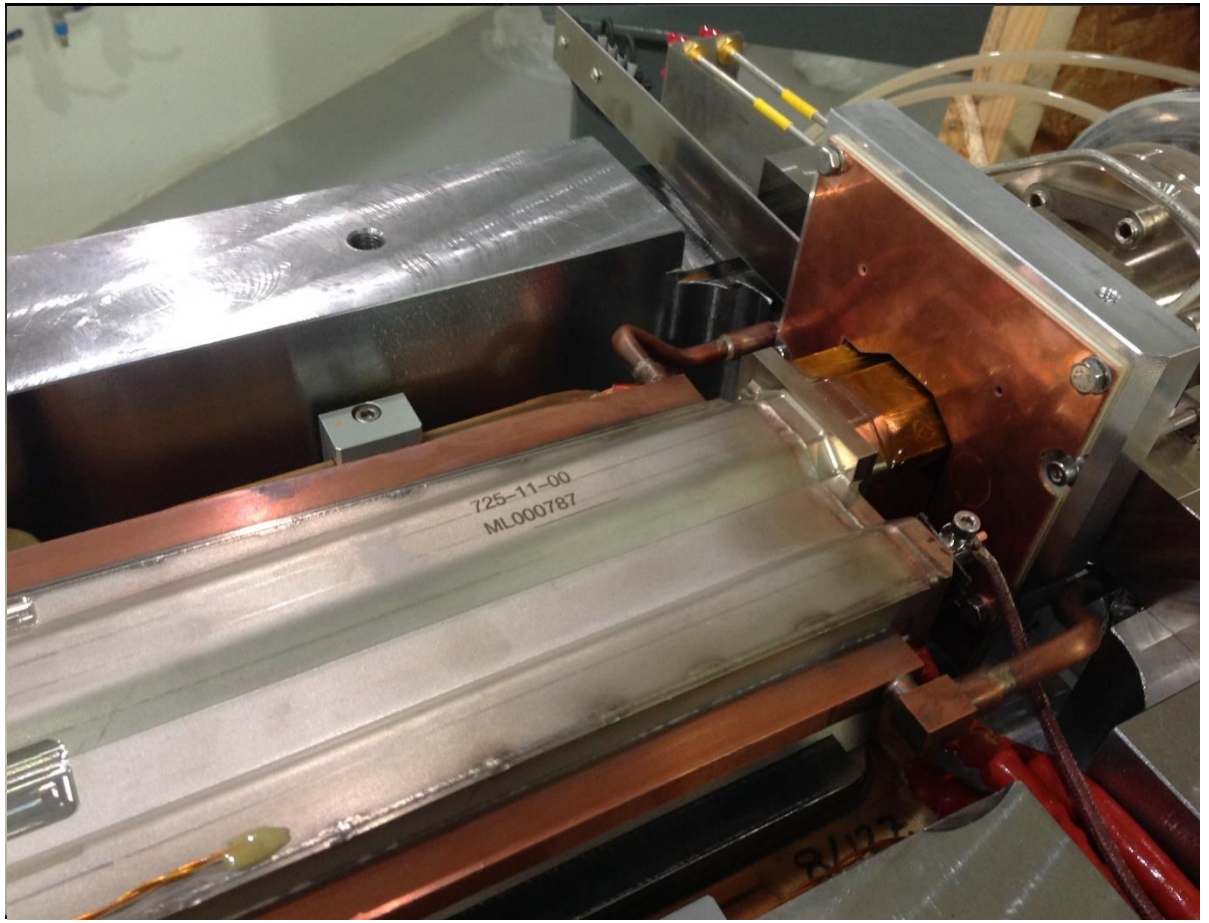


MACHINE FAILURES

Replacement of the dipole vacuum chamber in sector R1-02 - Lesson learnt

What we have learned from this accident?

- How expensive new VK2 vacuum chamber is
- How ceramic kicker chamber looks inside after 3 years of operation
- It is good to have spare parts, 13th spare dipole vacuum chamber was ready for installation
- We have the team ready to replace the damaged vacuum chamber without outsourcing support
- We have assembled with the vacuum chamber magnet for fast correct feedback system



MACHINE FAILURES

Replacement of the dipole vacuum chamber in sector R1-02

- 13th spare dipole vacuum chamber was ready for installation
- Two vacuum sectors R1-01 and R1-02 had to be vented
- Solaris Heating Unit Controller was used to activate NEG strips in dipole vacuum chamber in sectors R1-01 and R1-02

Proceedings of IPAC18, Vancouver, BC, Canada, THPAL107

W. Kitka at al. IPAC18 Proceedings Vancouver, BC, Canada, THPAL106

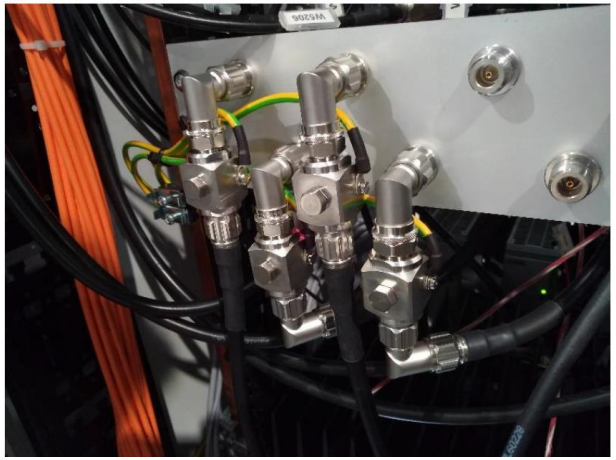
„HEATING UNIT CONTROLLER AT NSRC SOLARIS”

- Whole operation took less than 2 weeks

MACHINE FAILURES

Landau upper pick-up overheating

- Lots of HOM modes generated in the cavity
- No grids on pick-up ports–strong coupling
- Dominating frequencies around 1,5 and 1,9 GHz
- Frequent overheating of attenuators and loads
- Gas discharge tubes installed, to contain the problem
- Cable insulation melted, GDTs overheating, damaged RF N-type connector socket
- Bottom pickups do not cause any problems



MACHINE UPGRADES

Recent upgrades in the machine vacuum system

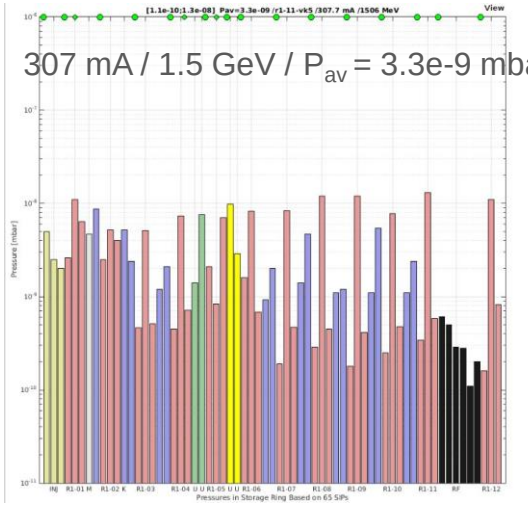
Installation of Residual Gas Analyzer

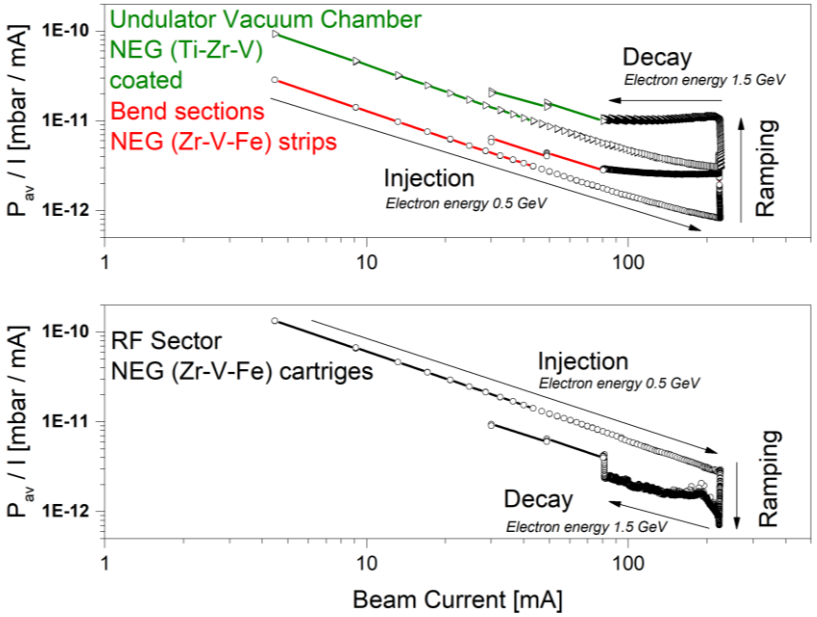
- Frond-ends: PEEM / UARPES beamlines


- Magnets R1-04 (XMCD) / R1-06 (PHELIX)


Integration of two TSP's with main cavities

Upgrade of two SIP's from Landau cavities with NEG's cartridges





Recent performance

Injection → Ramping → Decay

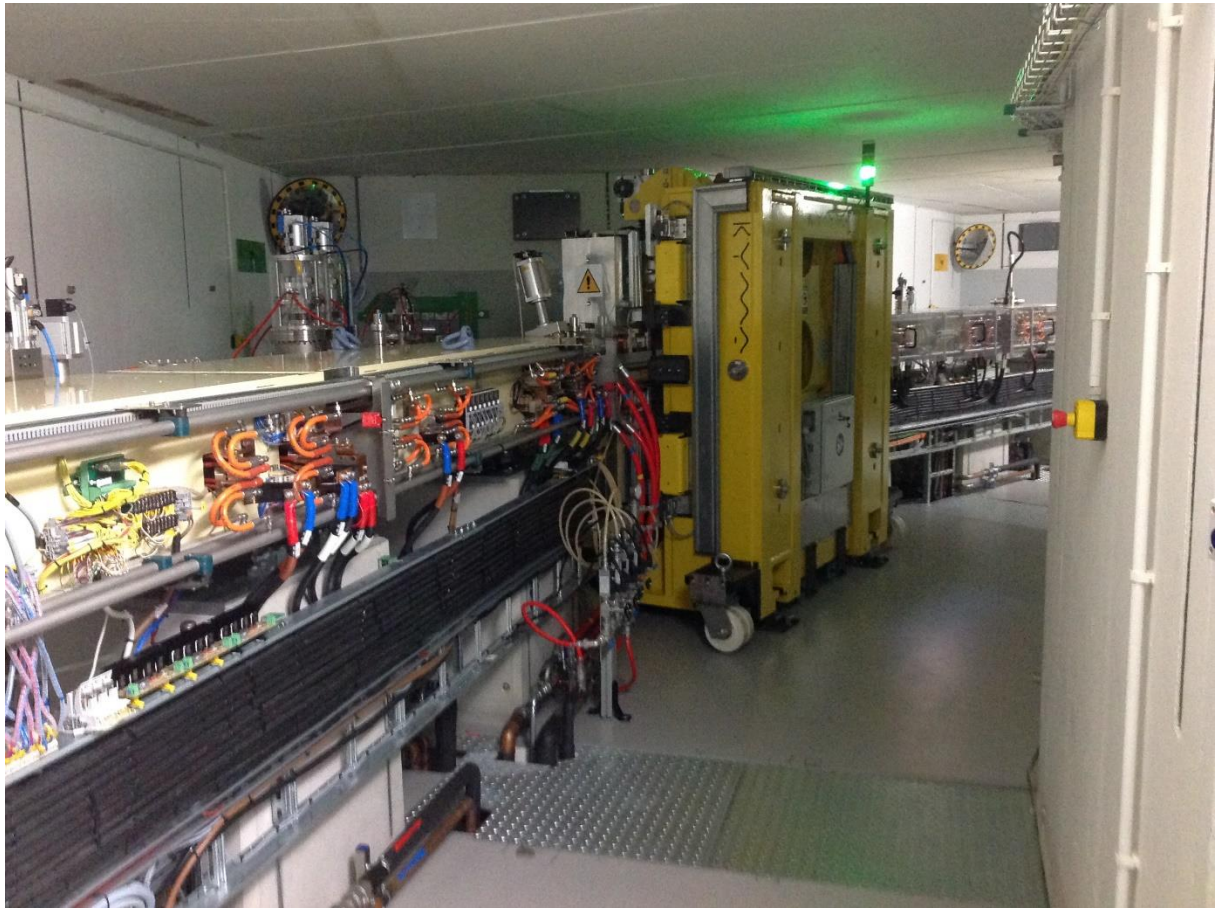
Unusual behavior of RF sector: pressure for electron energy 0.5 GeV is higher than for electron energy 1.5GeV

Why? Position of the plungers

MACHINE UPGRADES

Installation of Phelix vacuum ID section & Undulator

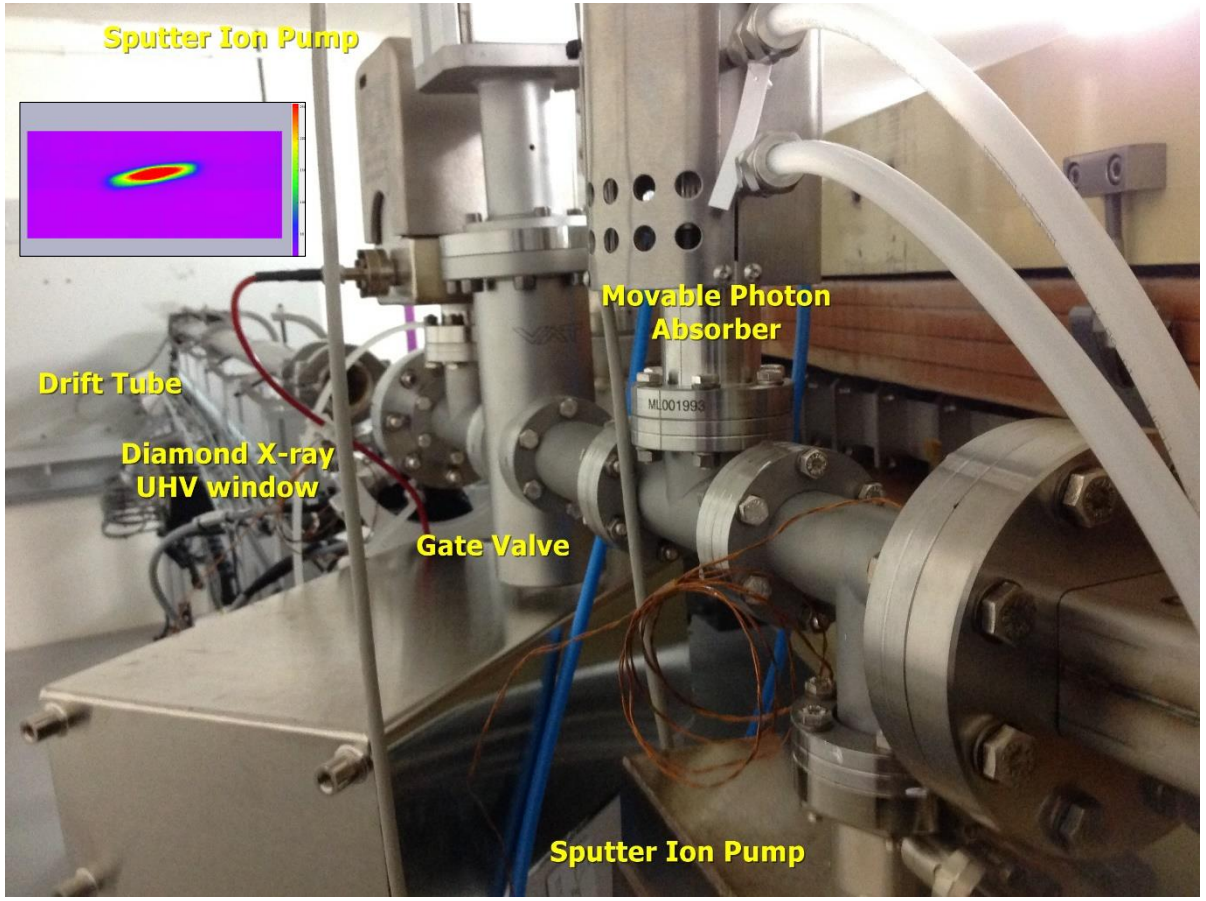
- According to the technical specification (SIWZ) the installation of vacuum parts to be performed by Solaris with Supervision FMB
- NEG activation process has been performed by Solaris Heating Unit Controller according to guidelines provided by FMB
- Leak check and residual gas analysis at the end of the process have been fulfilled, no contamination by hydrocarbons has been detected
- Average pressure based on two SIP's at the end of the process was in range ~3e-10 mbar
- In October the Phelix undulator was installed



MACHINE UPGRADES

Installation of Pinhole diagnostic beamline

- Diagnostic beamline was designed and installed by Solaris
- Vacuum parts has been assembled and bake-out outside of the storage ring
- Vacuum criteria regarding leak check and residual gas analysis at the end of the process have been fulfilled, no contamination by hydrocarbons has been detected



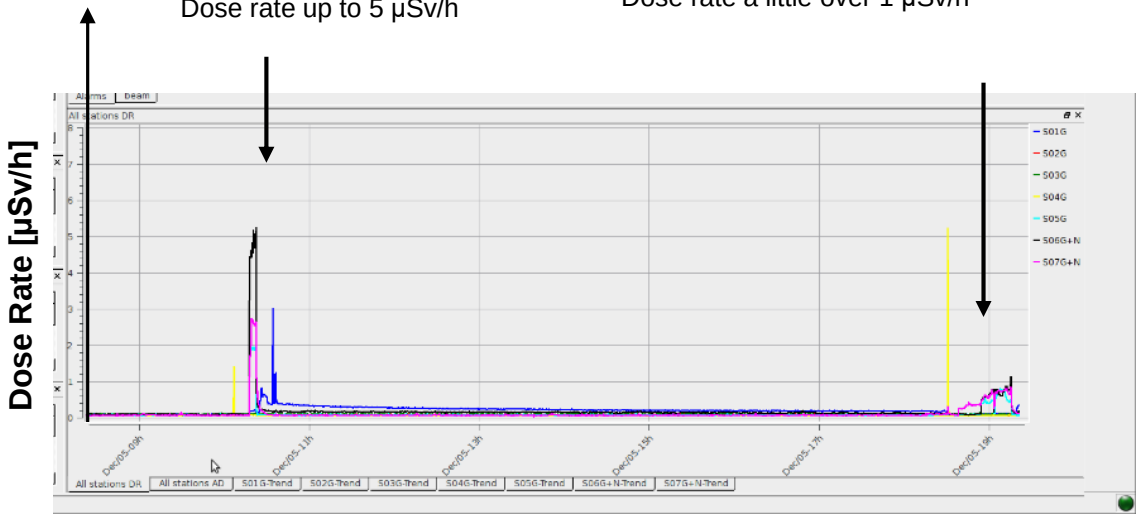
OPERATION IMPROVEMENTS

100 MHz chopper in the linac in operation

chopper

Lack of chopper
Dose rate up to 5 µSv/h

Chopper mode
Dose rate a little over 1 µSv/h



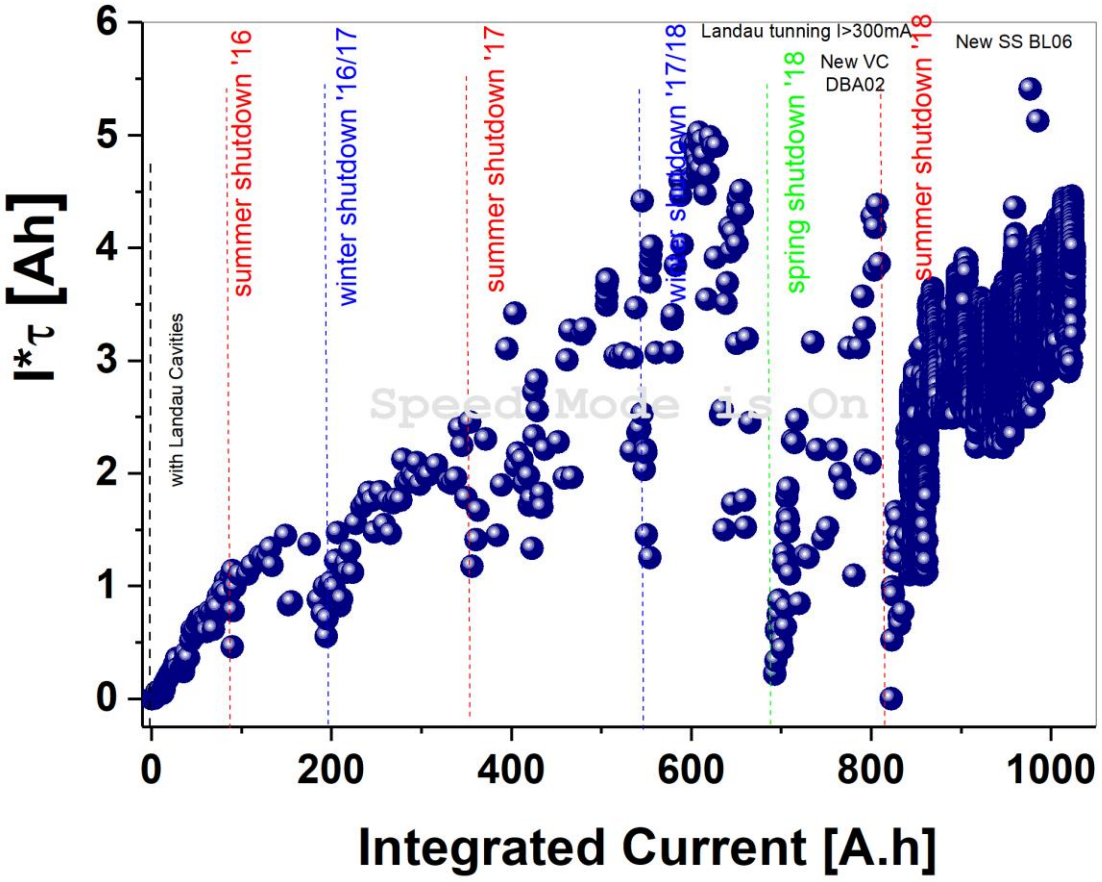
Bunch train shape at the end of the linac and in TL without chopper
Bunch train length ~180 ns, charge 3.6 nC
Injection efficiency up to 30%
Injection rate 1.4 mA/s

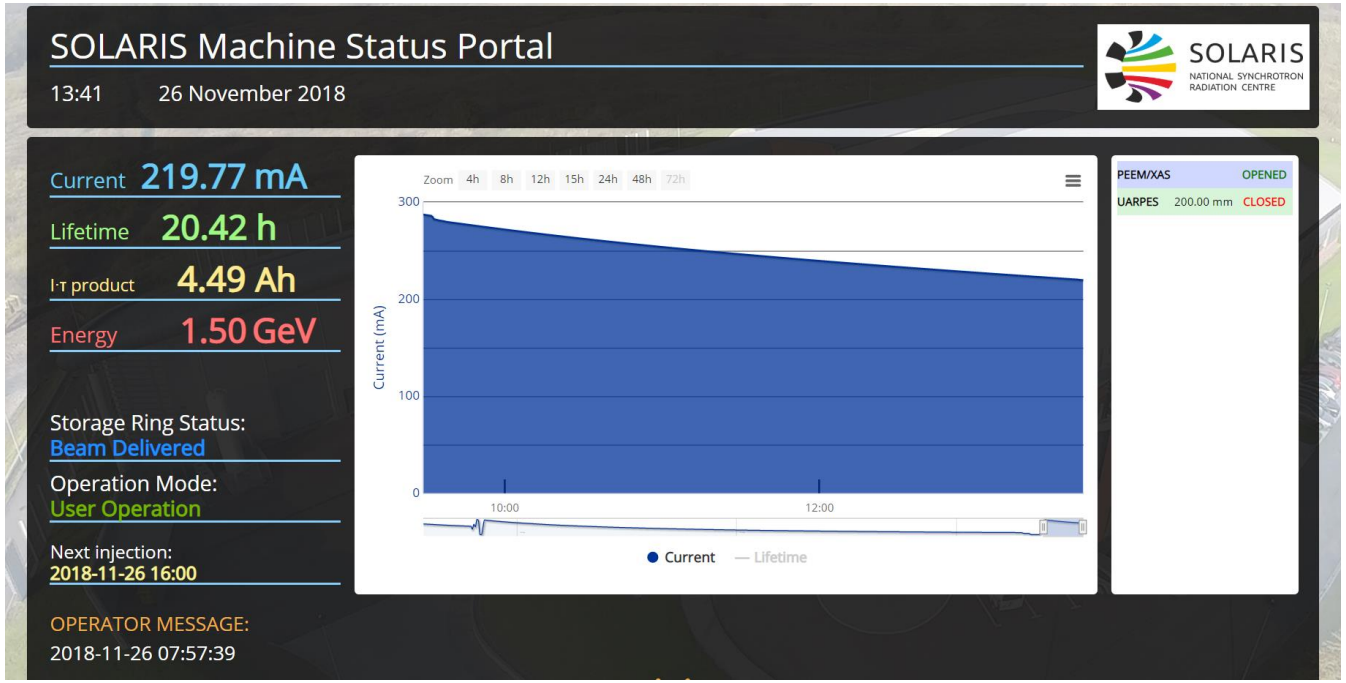
Bunch train shape at the end of the linac and in TL with chopper
Bunch train length ~100 ns, charge 0.6 nC
Injection efficiency between 45-60% -linac and ring optimisation
Injection rate 1 mA/s

Injection, LC tuning & ramping ~10min
Additional time need for LC fine tuning – few min.
Beam delivered average in 20 min

OPERATION IMPROVEMENTS

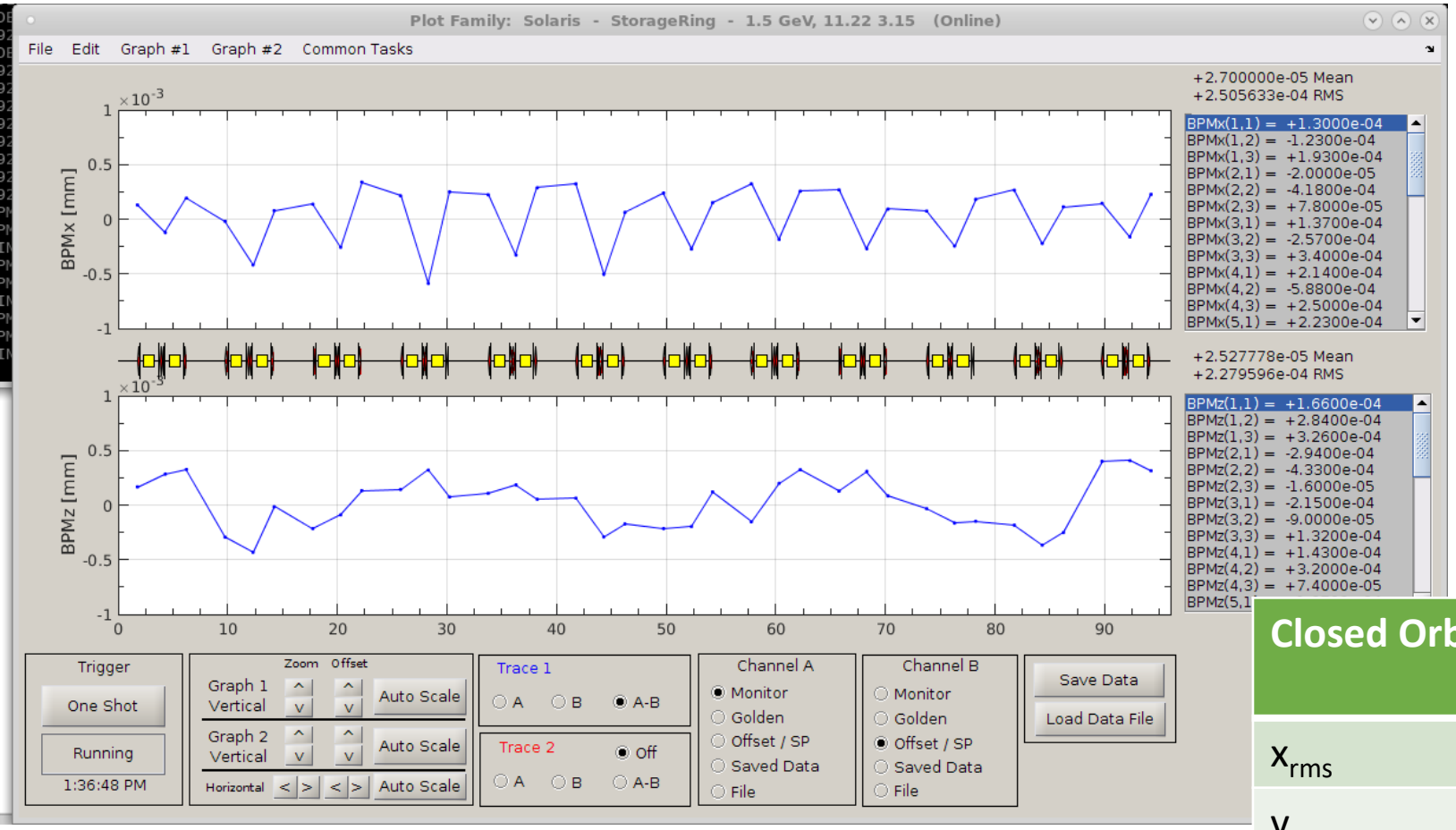
I*τ product with integrated current





OPERATION IMPROVEMENTS

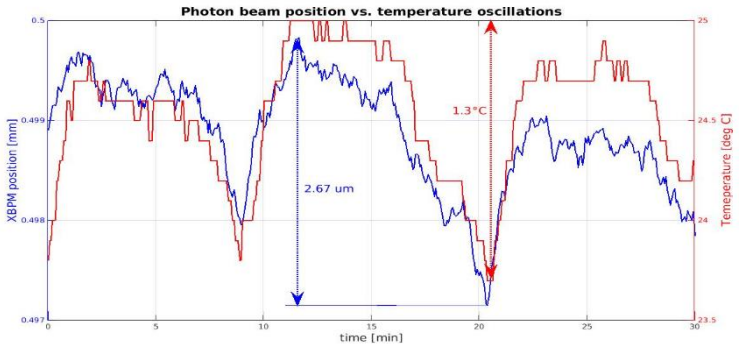
Closed orbit and orbit correction was improved with cooperation with Ward Wurtz from CLS (Saskatoon, Canada)

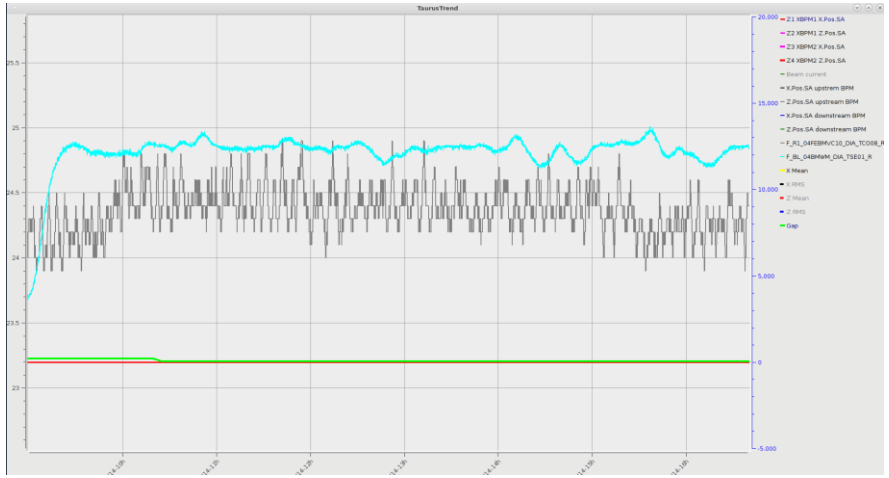


Closed Orbit	With correction &BBA before	With correction &BBA After
x_{rms}	160 μm	0.25 μm
y_{rms}	55 μm	0.22 μm

OPERATION IMPROVEMENTS

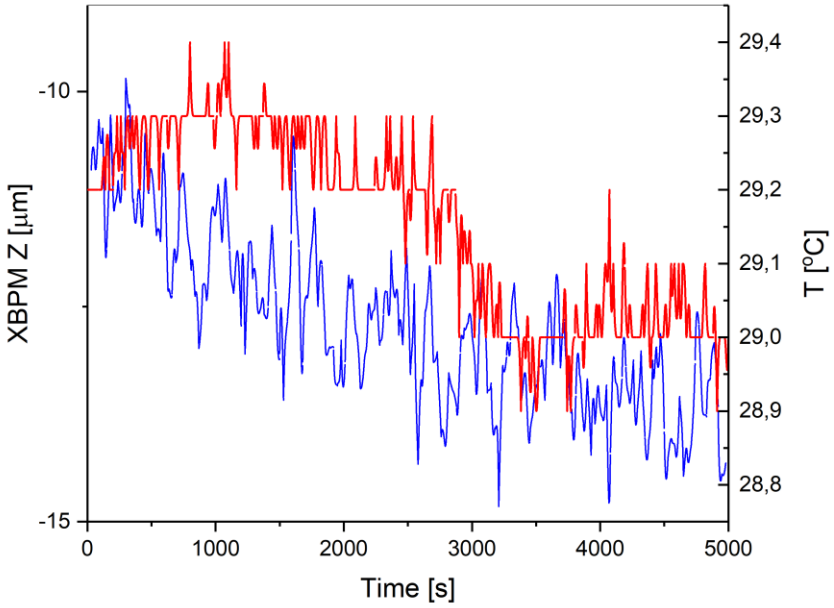
Photon beam oscillation with temperature oscillation





Temperature oscilation decreased to 0.6 °C

Temperature oscillations in the range of 1.5-2.0 °C
in the storage ring have impact on beam stabilty.

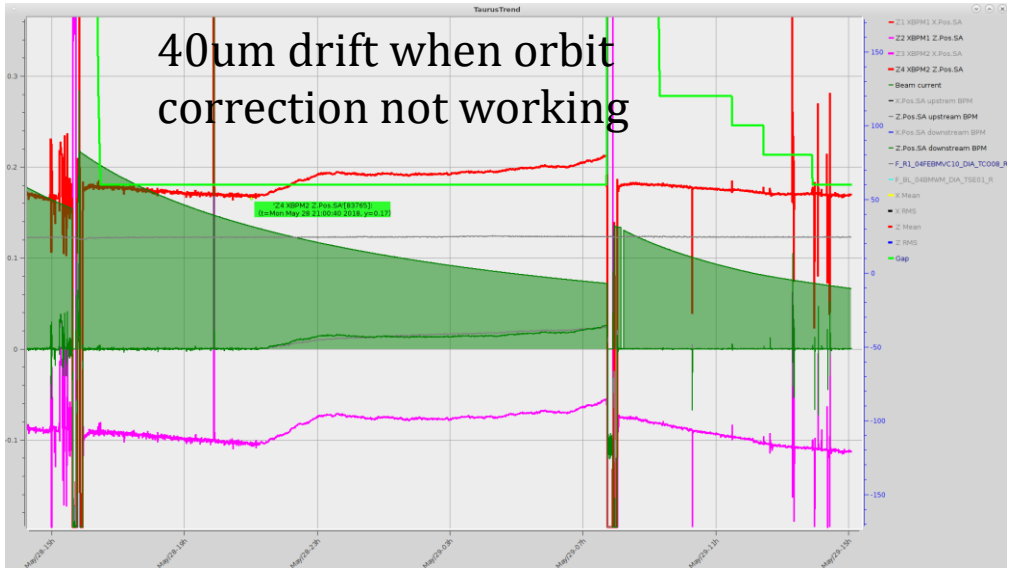


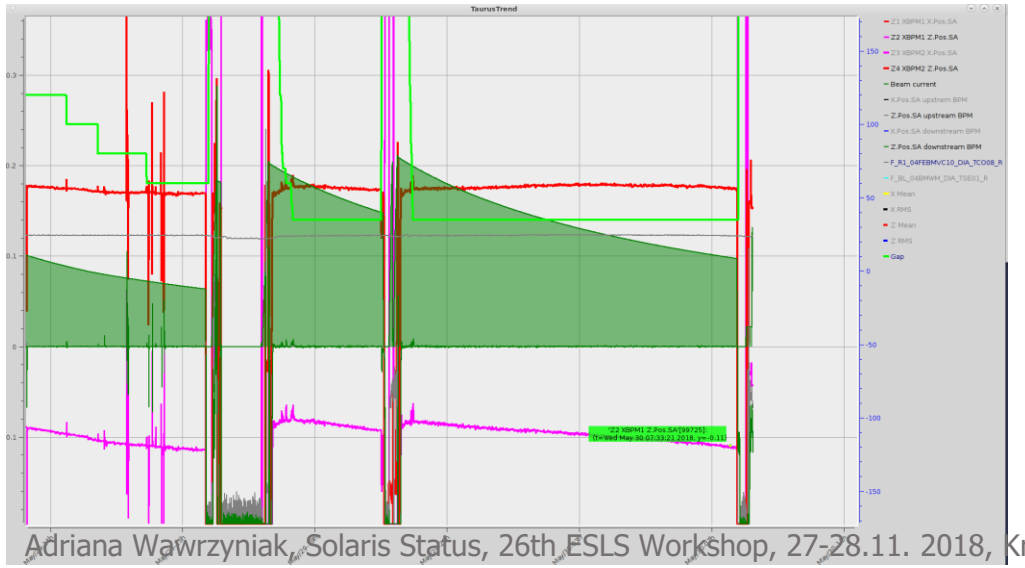
Photon beam stabilty requirements for PEEM/XAS beamline:

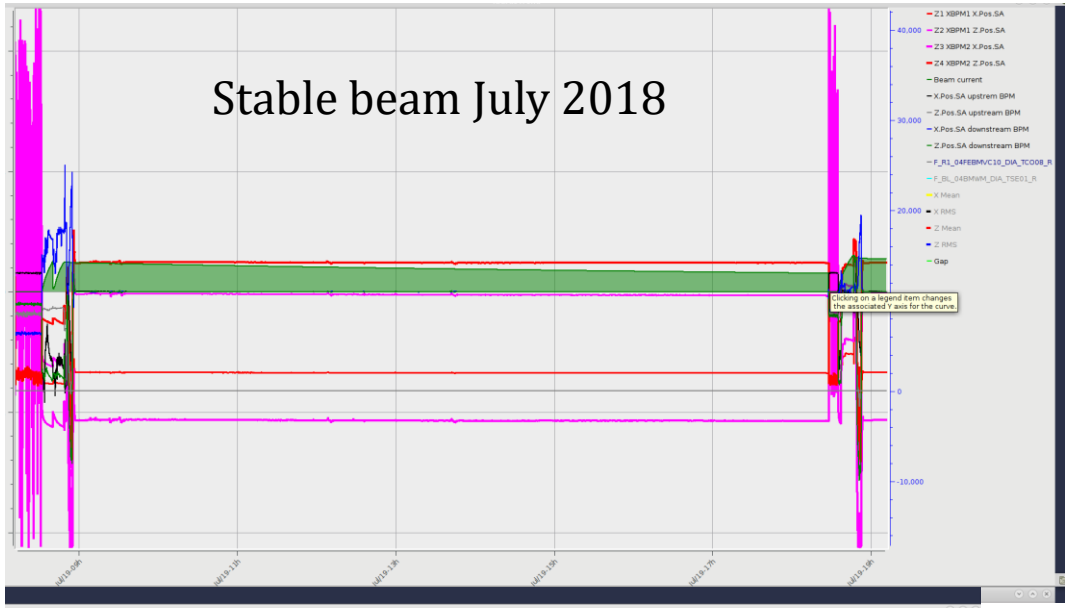
2 µm/8h → 50 meV/8h in a long run 50 meV/24h.
At the beginning try to obtain 5 µm/8h
Measured at XBPM1&2 in the FE

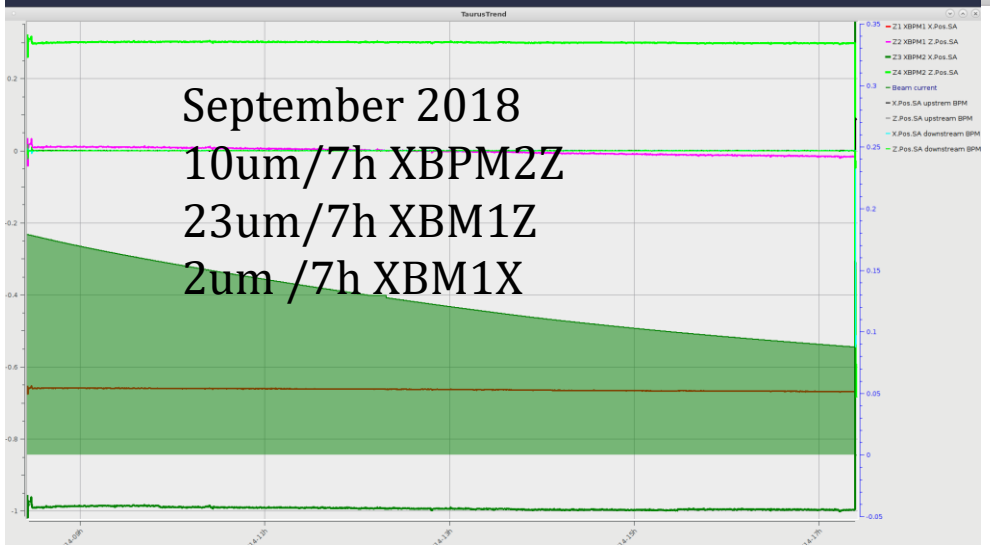
OPERATION IMPROVEMENTS

Long term beam stability – long term drift of photon beam



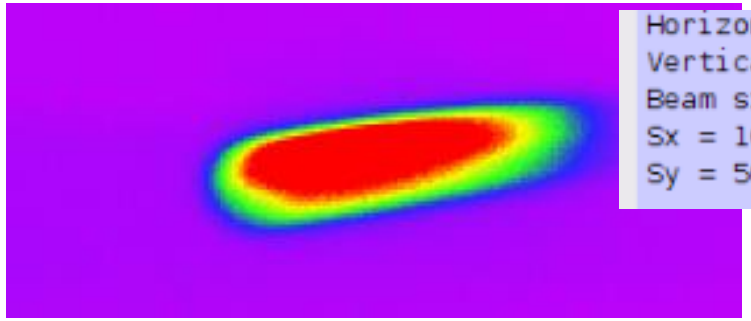




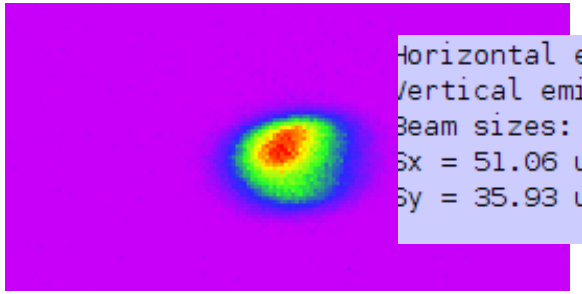


OPERATION IMPROVEMENTS

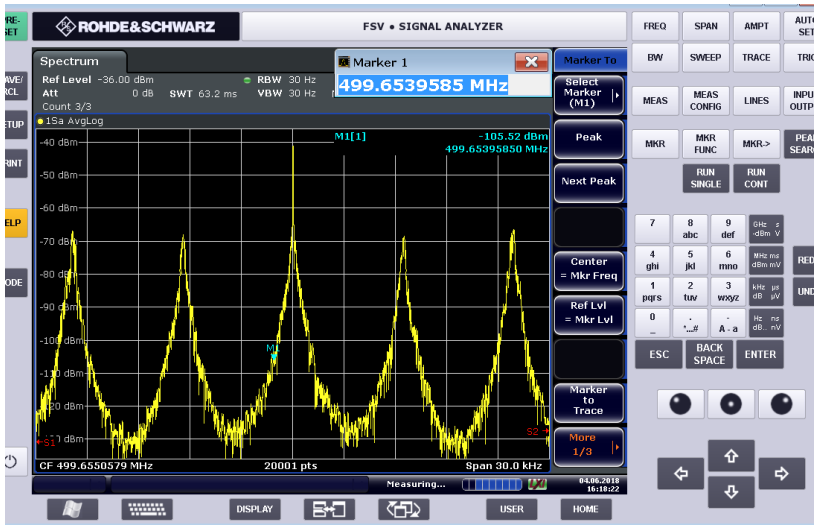
Landau cavities tuning-electron & photon beam profiles



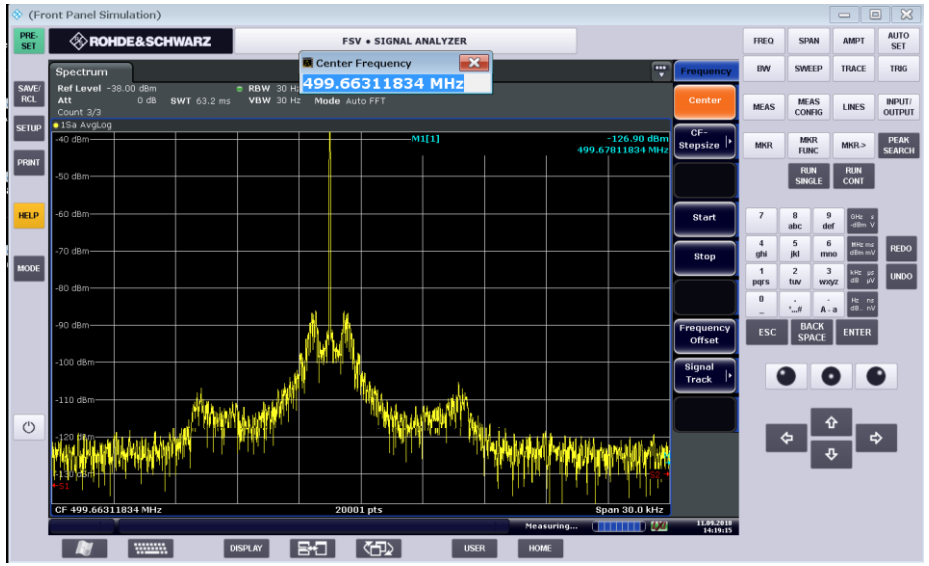
Horizontal emittance Ex = 121.40 [nm rad]
Vertical emittance Ey = 160.34 [pm rad]
Beam sizes:
Sx = 165.34 um
Sy = 50.30 um



Horizontal emittance Ex = 8.99 [nm rad]
Vertical emittance Ey = 81.83 [pm rad]
Beam sizes:
Sx = 51.06 um
Sy = 35.93 um



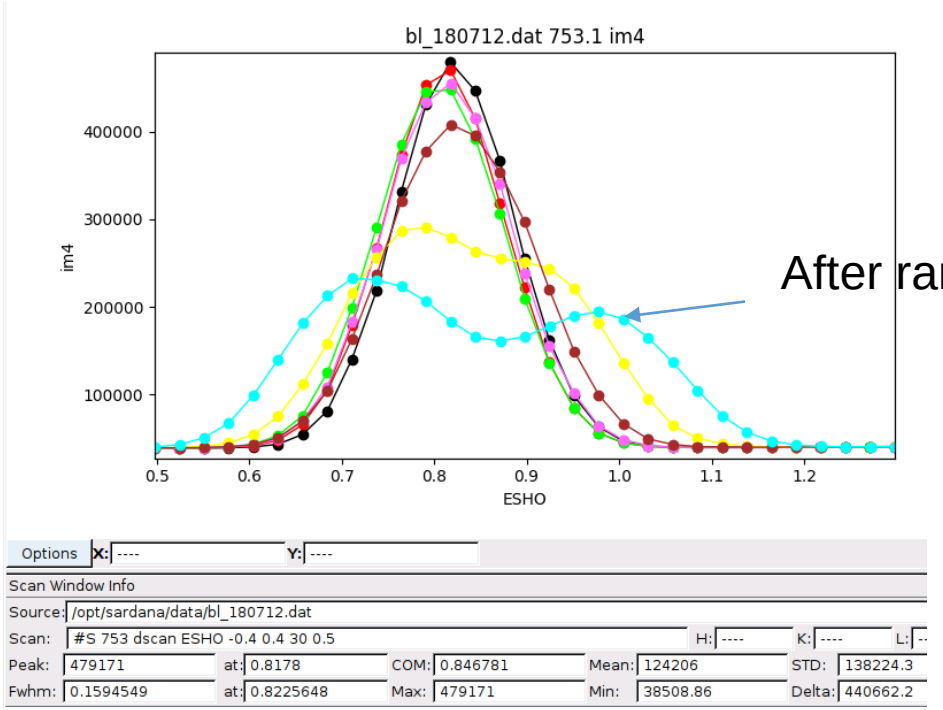
Injected current of 250mA @1.5GeV LC detuned
Plungers position 28 mm



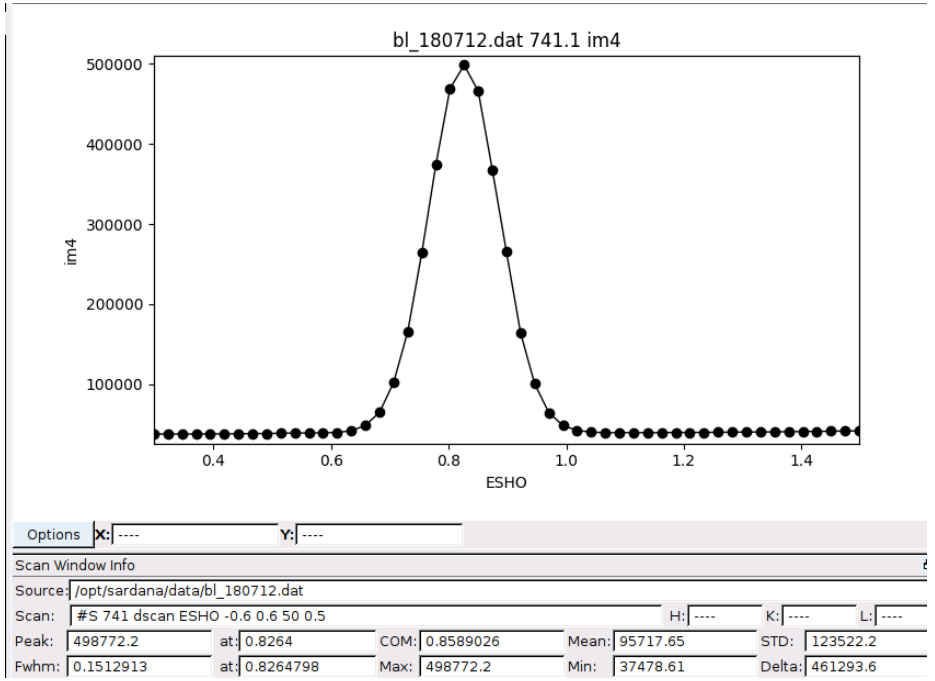
Injected current of 250mA @1.5GeV LC tuned
Plungers position 65 mm

OPERATION IMPROVEMENTS

Photon beam shape profile shape and the width dependence from the Landau tunning and beam current in the machine



After ramping

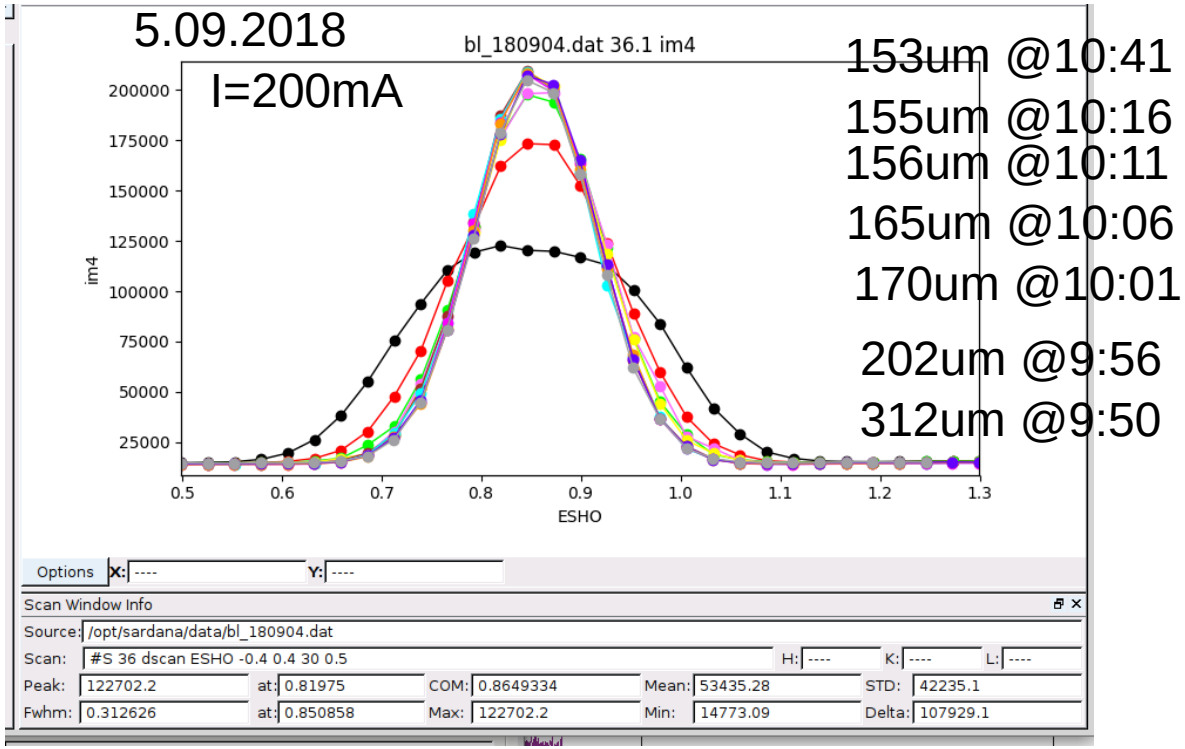


BEAM STABILITY

Repeatability and stability

- Tuning Landau Cavities
  - Not repeatable plungers positions – improved
  - Instabilities causing uncontrolled beam losses
  - Spectrum changes with current decay
- Beam profile depends also on time
- Beam profile depends on the current in the machine
- Seems to be repeatable at the same current and plungers position

Photon beam profile evolution with a time

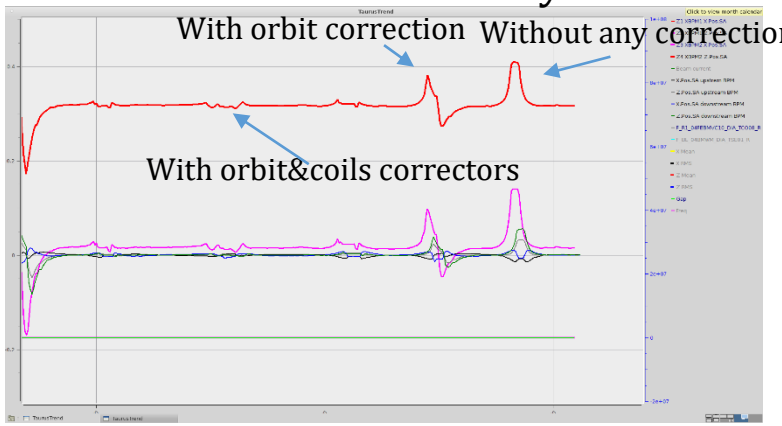


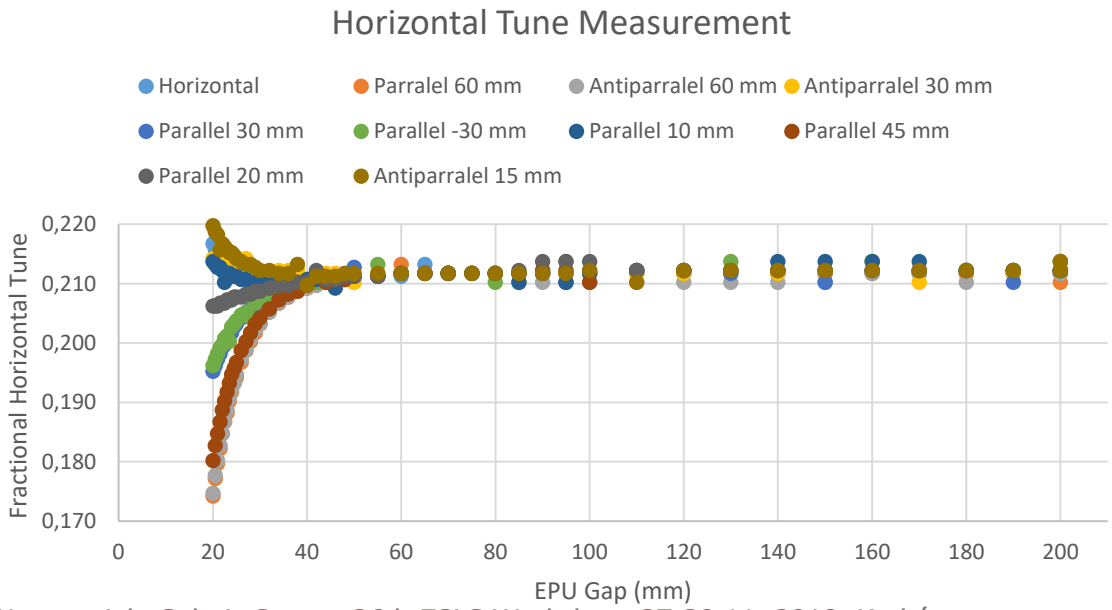
OPERATION IMPROVEMENTS

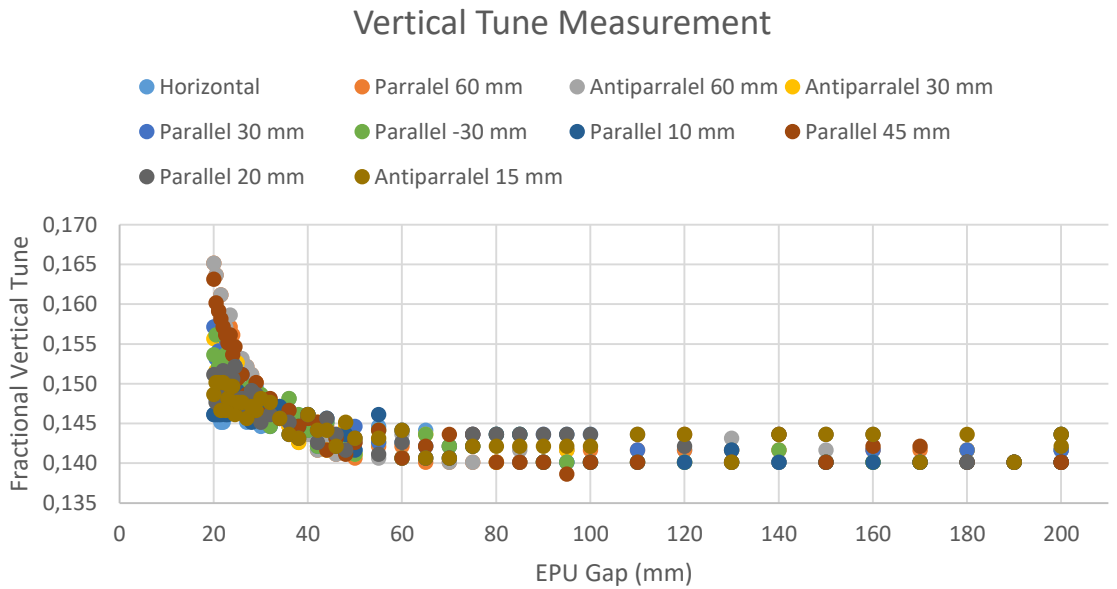
Undulator optimisation

- Impact on the photon beam during changing the gap
  - Correction coils matrix supplied by Kyma not working properly
  - Find the new matrix with the current setup – night shifts applying algorithm to find the best settings
  - Decreasing the disturbance from 60 um-2um for the phase 0, work ongoing to minimise the effect for other phases
  - Cooperation with Hamed Tarawneh from MAXIV Lab – visit planned for end of October
  - Optimisation of the lattice with respect of ID

Photon beam distortion by EPU







FUTURE PLANS

Linac and Transfer Line

- ✓ Continue with the emittance and energy spread measurements
- ✓ Continue with the optics adjustments for injection optimisation
- ✓ Chopper upgrade [waiting for electronics]
- ✓ Magnets settings optimisation at nominal energy after full conditioning and SLED tuning [future]
- ✓ Studies & optics design for the full energy linac

Storage Ring

- ✓ Beam stability improvement – insertion dev. Optimisation, LC optimisation [PRIORITY!]
- ✓ Beam dynamics with insertion devices studies
- ✓ Shunting the magnets based on LOCO [ahead]
- ✓ Nonlinear beam dynamics studies with pinger
- ✓ FOFB implementation – fast correctors procured, PS specification under preparation [in progress]
- ✓ Emittance measurements on PINHOLE beamline [in progress]
- ✓ Instabilities studies & cures [HOM couplers, BbBFeedback]

SUMMARY

Daily operation (Injections 8:00, 16:00-18:00 ; 21:30, current between 250-300mA)

Maintenance activities during shutdowns (active plan for repair – fixing magnets connection, valves connection replacement, short circuit in PFS removal etc.)

Chopper commissioning & injector optics optimisation

☺ Improved injection efficiency from 30% to 45%-60% - need further work

☺ Decreased the electron losses and radiation level (from 14uSv/h to 0.6uSv/h)

Focus on beam stability

☺ Closed orbit correction improvement

😐 Backbone water stability improvement

😐 Landau cavities tuning and instabilities supressing (ongoing)

😐 Suppressing impact of the UARPES EPU on the beam position (ongoing)

Installation and commissioning of the PINHOLE diagnostic beamline

Preparation for the installation of the VIS diagnostic beamline

Equipment development (tune measurement device, LLRF test stand, heating unit controller, vacuum pump station)

COOPERATION

Recent cooperation with other labs

- National Centre of Nuclear Research, Świerk, Poland –
  - vacuum installation support,
  - magnets alignment, sag measurements and removal
  - POLFEL project – SOLARIS part of the consortium
- MAXIV Laboratory, Lund, Sweden
  - Chopper & linac optics optimisation (David Olsson)
  - Landau Cavities tuning (Ake Andersson, Teresia Olsson)
  - Contact with RF, vacuum, CS, PLC and operators groups
  - EPU optimisation (Hamed Tarawneh)
- ALBA, Barcelona, Spain
  - LLRF test and workshop for Solaris (Angela Salom)
- Canadian Light Source, Saskatoon, Canada (Ward Wurtz)
  - Orbit correction optimisation
  - LOCO measurements
  - Nonlinear optics studies with/without ID
- BESSY II HZB, Berlin, Germany
  - 7T MPW
  - Hard X-ray beamline components

Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
ŚWIERK
instytut kategorii A+, JRC collaboration partner

MAX IV

ALBA

Canadian Light Source | Centre canadien de rayonnement synchrotron

HZB Helmholtz Zentrum Berlin

Thank you !

JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

National Synchrotron Radiation Center SOLARIS

Kraków, 27.11.18