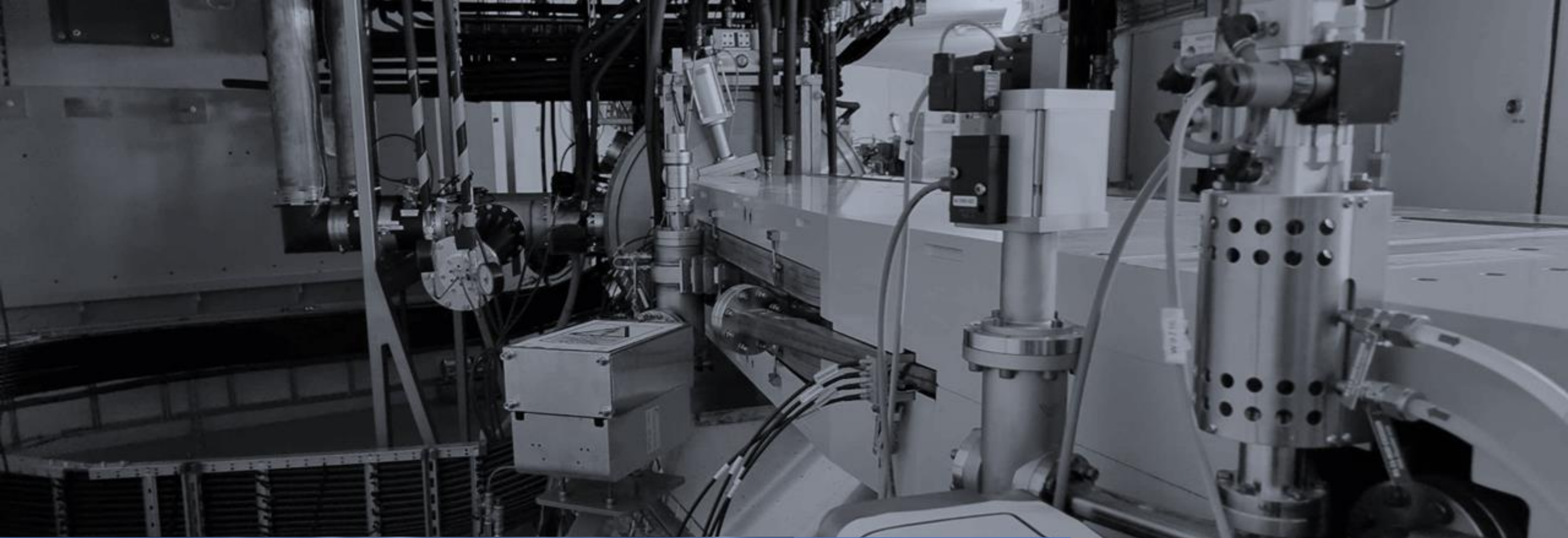


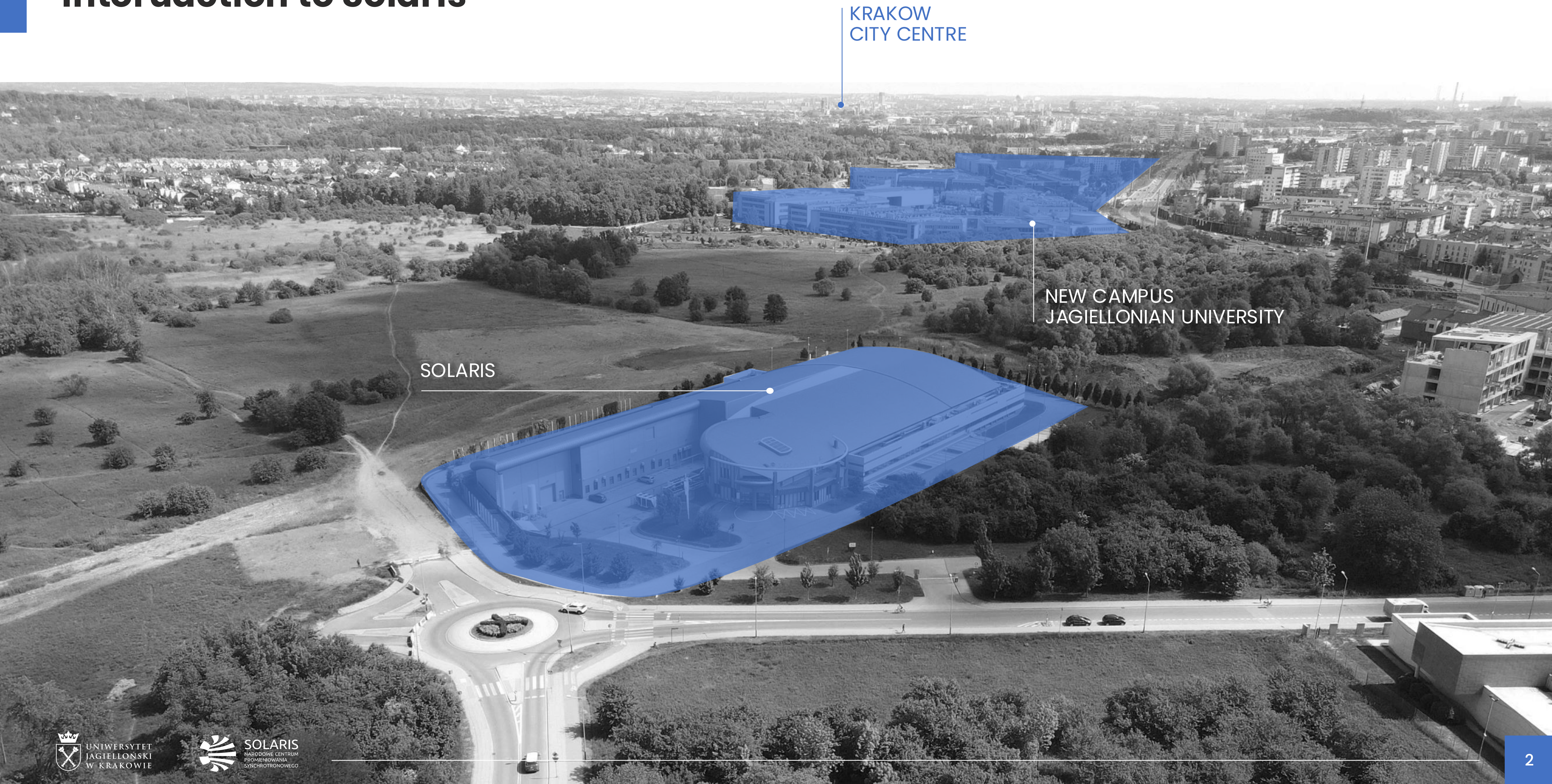
Status of Accelerators

Adriana Wawrzyniak, Roman Panaś

On behalf of Accelerators Department

ESLS, 29-31/10/2025

Intorudction to Solaris



SOLARIS Accelerators

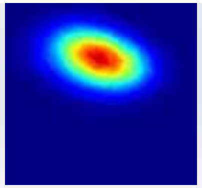
600 MeV Linac

- RF Thermionic Gun
- 6 S-band 2998.5 MHz accelerating
- structures
- Accelerating gradient 20 MeV/m
- 3 RF Units & SLED cavities
- Dog-leg vertical transfer line
- In operation since Dec. 2014

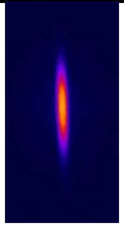
1.5GeV Storage ring

- 12 DBA Cells – 96 m circumference
- 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

PINHOLE



LUMOS



Parameter	Value
Energy	1.5 GeV
Max. current	500 mA
Harmonic number	32
Natural emittance	6 nmrad
Lifetime	13 h

Research Infrastructure

SOLARIS offers research at 7 synchrotron beamlines and at 2 Cryo-TEMs

Instruments available for users (12)

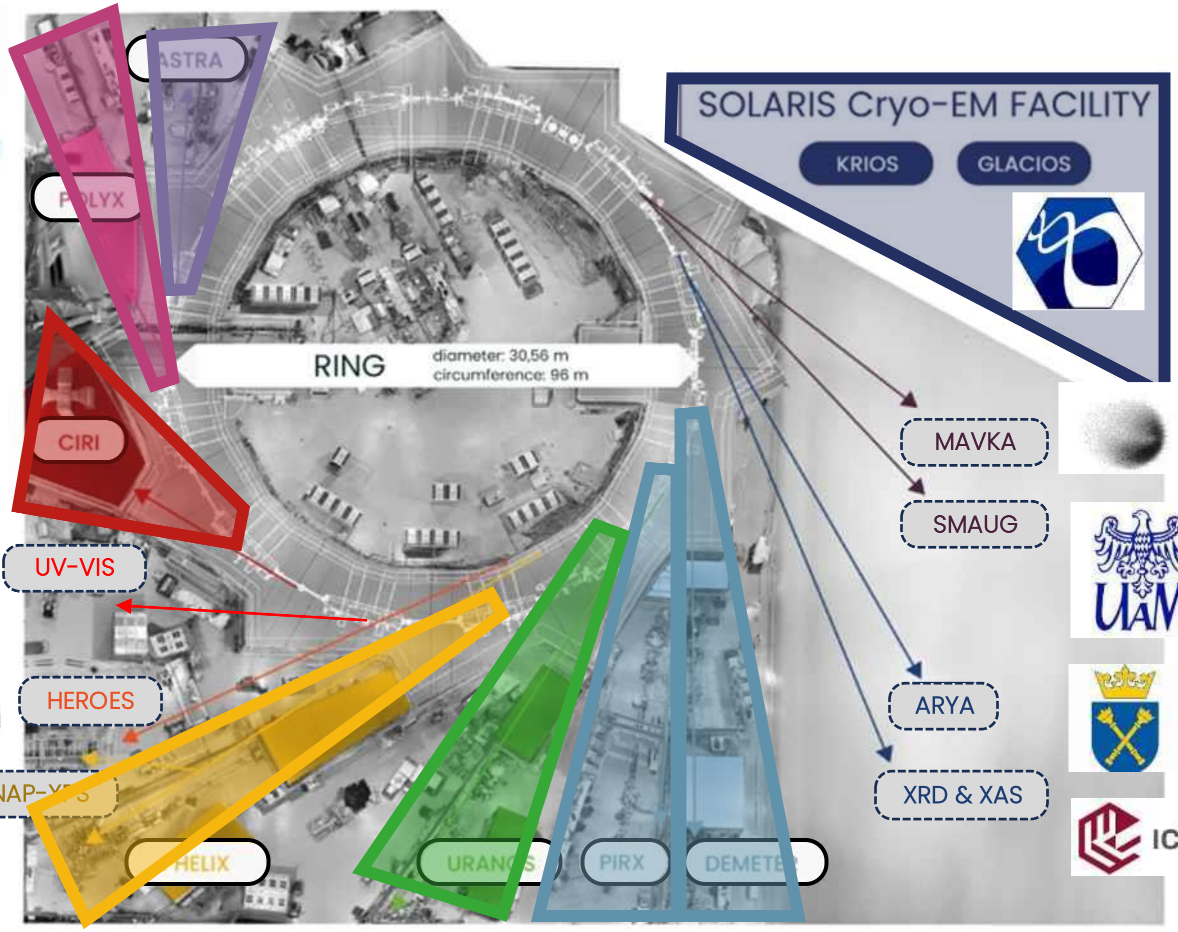
- IR microspectroscopy (3)
- VUV and soft X-ray spectroscopy at UHV (3)
- soft X-ray microscopy (2)
- tender & hard X-ray spectroscopy
- hard X-ray microscopy & tomography
- Cryo TEM (2)

Instruments under construction (5)

- X-ray photoemission at near AP
- macromocelular crystallography
- tender & hard X-ray micro/nano-beam
- small angle (hard) X-ray scattering
- hard X-ray spectroscopy, diffraction and inelastic scattering

Projects (5)

- Hard X-ray photoemission instrument
- Surface scattering instrument
- Operando RXES beamline
- UV-Vis and irradiation laboratory
- Next generation Cryo TEM



SOLARIS OPERATION: Operation Schedule

Jan 2025				Feb 2025				Mar 2025			
Wed 01	s	s	s	Sat 01	.	.	.	Sat 01	B	B	B
Thu 02	s	s	s	Sun 02	.	.	.	Sun 02	B	B	B
Fri 03	s	s	s	Mon 03	M	M	.	Mon 03	M	M	.
Sat 04	s	s	s	Tue 04	M	M	.	Tue 04	B	B	B
Sun 05	s	s	s	Wed 05	C	C	.	Wed 05	B	B	B
Mon 06	s	s	s	Thu 06	C	C	.	Thu 06	B	B	B
Tue 07	s	s	s	Fri 07	C	C	.	Fri 07	B	B	B
Wed 08	s	s	s	Sat 08	.	.	.	Sat 08	B	B	B
Thu 09	s	s	s	Sun 09	.	.	.	Sun 09	B	B	B
Fri 10	s	s	s	Mon 10	M	M	.	Mon 10	M	M	.
Sat 11	s	s	s	Tue 11	B	B	B	Tue 11	B	B	B
Sun 12	s	s	s	Wed 12	B	B	B	Wed 12	B	B	B
Mon 13	s	s	s	Thu 13	B	B	B	Thu 13	B	B	B
Tue 14	s	s	s	Fri 14	B	B	B	Fri 14	B	B	B
Wed 15	s	s	s	Sat 15	B	B	B	Sat 15	B	B	B
Thu 16	s	s	s	Sun 16	.	.	.	Sun 16	B	B	B
Fri 17	s	s	s	Mon 17	M	M	.	Mon 17	M	M	.
Sat 18	s	s	s	Tue 18	B	B	B	Tue 18	B	B	B
Sun 19	s	s	s	Wed 19	B	B	B	Wed 19	B	B	B
Mon 20	O	.	.	Thu 20	B	B	B	Thu 20	B	B	B
Tue 21	O	.	.	Fri 21	B	B	B	Fri 21	B	B	B
Wed 22	O	.	.	Sat 22	B	B	B	Sat 22	B	B	B
Thu 23	M	M	.	Sun 23	B	B	B	Sun 23	B	B	B
Fri 24	M	M	.	Mon 24	M	M	.	Mon 24	M	M	.
Sat 25	.	.	.	Tue 25	B	B	B	Tue 25	B	B	B
Sun 26	.	.	.	Wed 26	B	B	B	Wed 26	B	B	B
Mon 27	M	M	.	Thu 27	B	B	B	Thu 27	B	B	B
Tue 28	M	M	.	Fri 28	B	B	B	Fri 28	B	B	B
Wed 29	M	M	.					Sat 29	B	B	B
Thu 30	M	M	.					Sun 30	B	B	B
Fri 31	M	M	.					Mon 31	M	M	.

Apr 2025				May 2025				Jun 2025			
Tue 01	B	B	B	Thu 01	s	s	s	Sun 01	B	B	B
Wed 02	B	B	B	Fri 02	s	s	s	Mon 02	M	M	.
Thu 03	B	B	B	Sat 03	s	s	s	Tue 03	B	B	B
Fri 04	B	B	B	Sun 04	s	s	s	Wed 04	B	B	B
Sat 05	B	B	B	Mon 05	s	s	s	Thu 05	B	B	B
Sun 06	B	B	B	Tue 06	s	O	.	Fri 06	B	B	B
Mon 07	M	M	.	Wed 07	M	M	.	Sat 07	B	B	B
Tue 08	B	B	B	Thu 08	M	M	.	Sun 08	B	B	B
Wed 09	B	B	B	Fri 09	M	M	.	Mon 09	M	M	.
Thu 10	B	B	B	Sat 10	.	.	.	Tue 10	B	B	B
Fri 11	B	B	B	Sun 11	.	.	.	Wed 11	B	B	B
Sat 12	B	B	B	Mon 12	M	M	.	Thu 12	B	B	B
Sun 13	B	B	B	Tue 13	C	C	.	Fri 13	B	B	B
Mon 14	M	M	.	Wed 14	B	B	B	Sat 14	B	B	B
Tue 15	M	M	.	Thu 15	B	B	B	Sun 15	B	B	B
Wed 16	M	M	.	Fri 16	B	B	B	Mon 16	M	M	.
Thu 17	M	M	.	Sat 17	B	B	B	Tue 17	B	B	B
Fri 18	M	.	.	Sun 18	B	B	B	Wed 18	B	B	B
Sat 19	.	.	.	Mon 19	M	M	.	Thu 19	.	.	.
Sun 20	.	.	.	Tue 20	B	B	B	Fri 20	.	.	.
Mon 21	.	.	.	Wed 21	B	B	B	Sat 21	.	.	.
Tue 22	M	M	.	Thu 22	B	B	B	Sun 22	.	.	.
Wed 23	B	B	B	Fri 23	B	B	B	Mon 23	M	M	.
Thu 24	B	B	B	Sat 24	B	B	B	Tue 24	B	B	B
Fri 25	B	B	B	Sun 25	B	B	B	Wed 25	B	B	B
Sat 26	B	B	B	Mon 26	M	M	.	Thu 26	B	B	B
Sun 27	B	B	B	Tue 27	B	B	B	Fri 27	B	B	B
Mon 28	s	s	s	Wed 28	B	B	B	Sat 28	B	B	B
Tue 29	s	s	s	Thu 29	B	B	B	Sun 29	B	B	B
Wed 30	s	s	s	Fri 30	B	B	B	Mon 30	M	M	.
				Sat 31	B	B	B				

Jul 2025				Aug 2025				Sep 2025			
Tue 01	B	B	B	Fri 01	s	s	s	Mon 01	M	M	.
Wed 02	B	B	B	Sat 02	s	s	s	Tue 02	M	M	.
Thu 03	B	B	B	Sun 03	s	s	s	Wed 03	C	C	.
Fri 04	B	B	B	Mon 04	s	s	s	Thu 04	C	C	.
Sat 05	B	B	B	Tue 05	s	s	s	Fri 05	C	C	.
Sun 06	B	B	B	Wed 06	s	s	s	Sat 06	.	.	.
Mon 07	M	M	.	Thu 07	s	s	s	Sun 07	.	.	.
Tue 08	B	B	B	Fri 08	s	s	s	Mon 08	M	M	.
Wed 09	B	B	B	Sat 09	s	s	s	Tue 09	B	B	B
Thu 10	B	B	B	Sun 10	s	s	s	Wed 10	B	B	B
Fri 11	B	B	B	Mon 11	s	s	s	Thu 11	B	B	B
Sat 12	B	B	B	Tue 12	s	s	s	Fri 12	B	B	B
Sun 13	B	B	B	Wed 13	s	s	s	Sat 13	B	B	B
Mon 14	M	s	s	Thu 14	s	s	s	Sun 14	B	B	B
Tue 15	s	s	s	Fri 15	s	s	s	Mon 15	M	M	.
Wed 16	s	s	s	Sat 16	s	s	s	Tue 16	B	B	B
Thu 17	s	s	s	Sun 17	s	s	s	Wed 17	B	B	B
Fri 18	s	s	s	Mon 18	O	.	.	Thu 18	B	B	B
Sat 19	s	s	s	Tue 19	O	.	.	Fri 19	B	B	B
Sun 20	s	s	s	Wed 20	O	.	.	Sat 20	B	B	B
Mon 21	s	s	s	Thu 21	M	M	.	Sun 21	B	B	B
Tue 22	s	s	s	Fri 22	M	M	.	Mon 22	M	M	.
Wed 23	s	s	s	Sat 23	.	.	.	Tue 23	B	B	B
Thu 24	s	s	s	Sun 24	.	.	.	Wed 24	B	B	B
Fri 25	s	s	s	Mon 25	M	M	.	Thu 25	B	B	B
Sat 26	s	s	s	Tue 26	M	M	.	Fri 26	B	B	B
Sun 27	s	s	s	Wed 27	M	M	.	Sat 27	B	B	B
Mon 28	s	s	s	Thu 28	M	M	.	Sun 28	B	B	B
Tue 29	s	s	s	Fri 29	M	M	.	Mon 29	M	M	.
Wed 30	s	s	s	Sat 30	.	.	.	Tue 30	B	B	B
Thu 31	s	s	s	Sun 31	.	.	.				

Oct 2025				Nov 2025				Dec 2025			
Wed 01	B	B	B	Sat 01	.	.	.	Mon 01	M	M	.
Thu 02	B	B	B	Sun 02	.	.	.	Tue 02	B	B	B
Fri 03	B	B	B	Mon 03	M	M	.	Wed 03	B	B	B
Sat 04	B	B	B	Tue 04	C	C	.	Thu 04	B	B	B
Sun 05	B	B	B	Wed 05	B	B	B	Fri 05	B	B	B
Mon 06	M	M	.	Thu 06	B	B	B	Sat 06	B	B	B
Tue 07	B	B	B	Fri 07	B	B	B	Sun 07	B	B	B
Wed 08	B	B	B	Sat 08	B	B	B	Mon 08	M	M	.
Thu 09	B	B	B	Sun 09	B	B	B	Tue 09	B	B	B
Fri 10	B	B	B	Mon 10	M	M	.	Wed 10	B	B	B
Sat 11	B	B	B	Tue 11	.	.	.	Thu 11	B	B	B
Sun 12	B	B	B	Wed 12	B	B	B	Fri 12	B	B	B
Mon 13	M	M	.	Thu 13	B	B	B	Sat 13	B	B	B
Tue 14	B	B	B	Fri 14	B	B	B	Sun 14	B	B	B
Wed 15	B	B	B	Sat 15	B	B	B	Mon 15	M	M	.
Thu 16	B	B	B	Sun 16	B	B	B	Tue 16	M	M	.
Fri 17	B	B	B	Mon 17	M	M	.	Wed 17	M	M	.
Sat 18	B	B	B	Tue 18	B	B	B	Thu 18	M	M	.
Sun 19	B	B	B	Wed 19	B	B	B	Fri 19	M	s	s
Mon 20	M	M	.	Thu 20	B	B	B	Sat 20	s	s	s
Tue 21	M	M	.	Fri 21	B	B	B	Sun 21	s	s	s
Wed 22	M	M	.	Sat 22	B	B	B	Mon 22	s	s	s
Thu 23	M	M	.	Sun 23	B	B	B	Tue 23	s	s	s
Fri 24	M	M		Mon 24	M	M	.	Wed 24	s	s	s
Sat 25	.	.	.	Tue 25	B	B	B	Thu 25	s	s	s
Sun 26	.	.	.	Wed 26	B	B	B	Fri 26	s	s	s
Mon 27	s	s	s	Thu 27	B	B	B	Sat 27	s	s	s
Tue 28	s	s	s	Fri 28	B	B	B	Sun 28	s	s	s
Wed 29	s	s	s	Sat 29	B	B	B	Mon 29	s	s	s
Thu 30	s	s	s	Sun 30	B	B	B	Tue 30	s	s	s
Fri 31	O	.	.					Wed 31	s	s	s

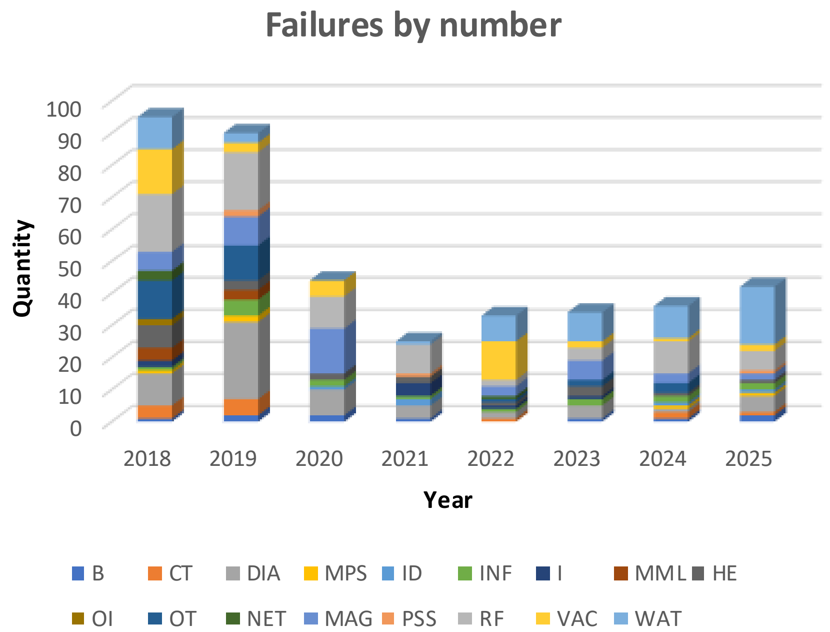
Beam for beamlines/Users	Machine development /maintenance	Shutdown
185 days/year	75 days/year	79 days/year

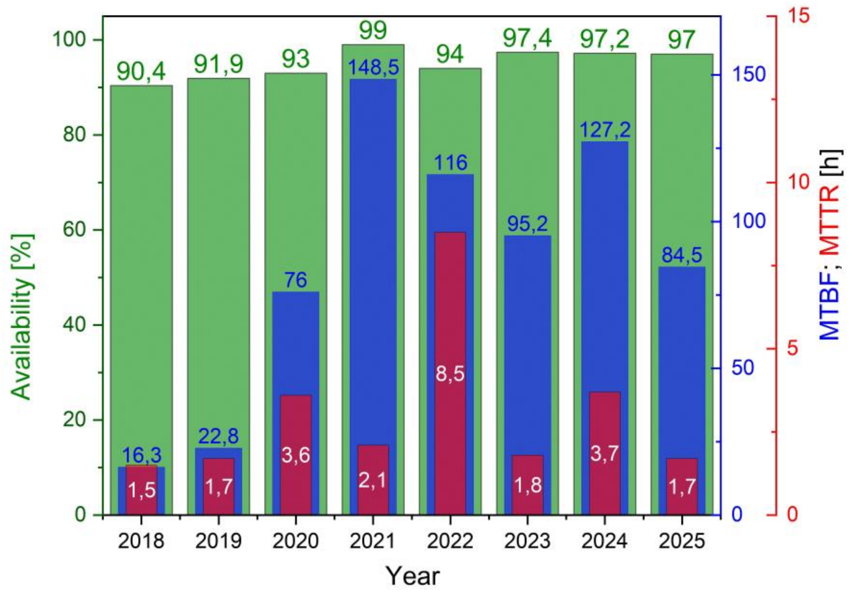
STANDRAD OPERATION 24/7 since 2025r.

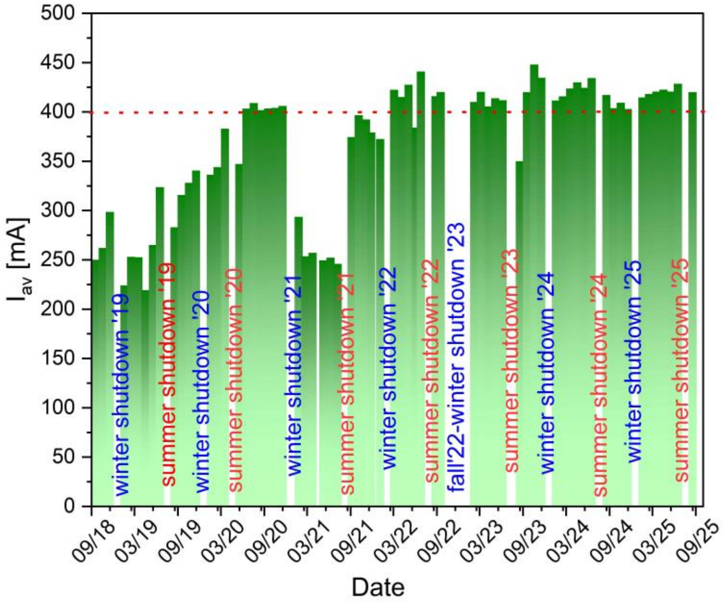
- 2 shifts (8:00-16:00; 14:00-22:00),
- Mondays (from 8:00 am) for machine studies, developments and maintenance
- Tue-Mon (until 8:00 am) –User Operation
- On-call duties 22:00-2:00
- Operation in decay mode, full filling pattern
- 2 injections/day

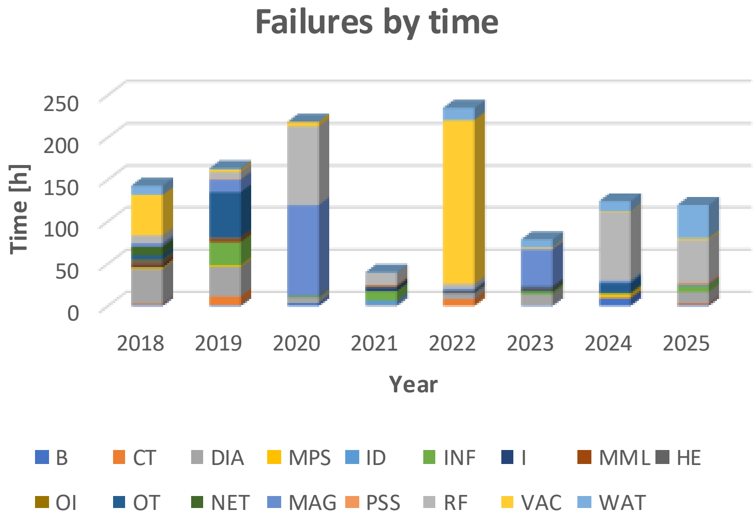
SOLARIS OPERATION: STATISTICS

User time	Availability	MTBF	MTTR
3970h	97.0%	84.5h	1.7h





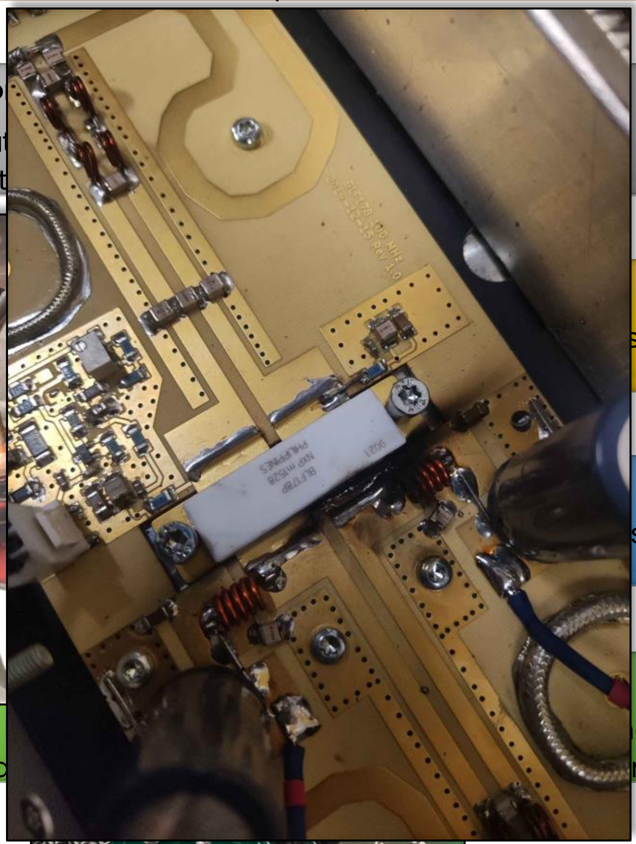




Main Failures

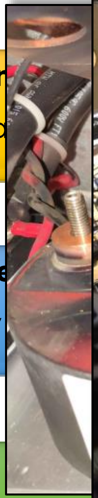
RF Chopper – 100MHz pulsed amplifier failure

- At the beginning of 2025, the RF power pulsed amplifier of the 100MHz chopper was damaged, without apparent cause. The LDMOS power transistor burned out. Amplifier and preamplifier modules was repaired and the transistor was replaced.



High Power Switching Unit (HPSU) for modulato

- Several switching modules HPSU in the modulat … IGBT transistors were failing. The transistors used are no longer manufactured, and we are working on ut…



Timing system: Kontron CP6004 CPU r

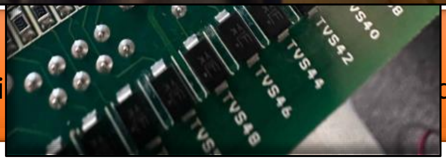
- Several damaged boards. Our approa… some time. Next step is to replace chip to another one. New parts are not available.

Libera Brilliance RAF modules damage

- Around once per 6 months randomly … s easy and takes half an hour: just replace four 10 uF 0805 capacitors.

Water circuit interlocks in storage ring

- Problems with water flow inside the coils of the … ew portable monitoring system (Watson) for temperature detection in critical regions. Design and manufa… n)

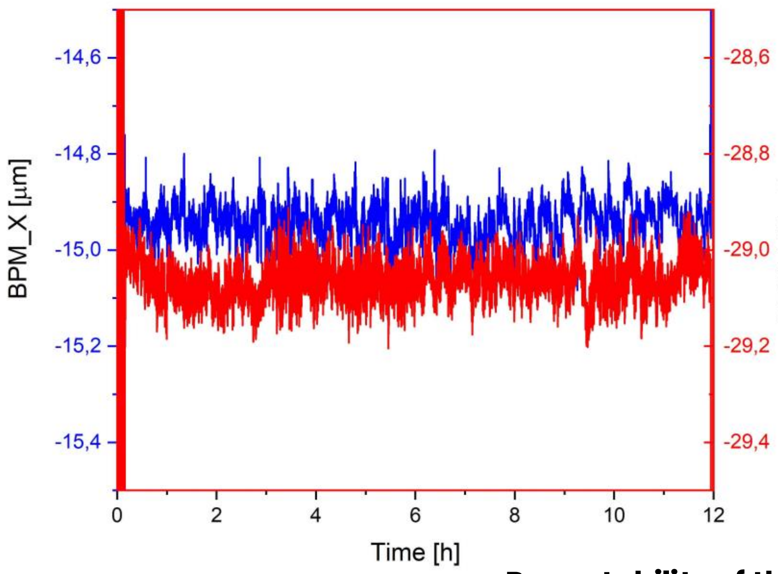


Water interlocks on main power supplies

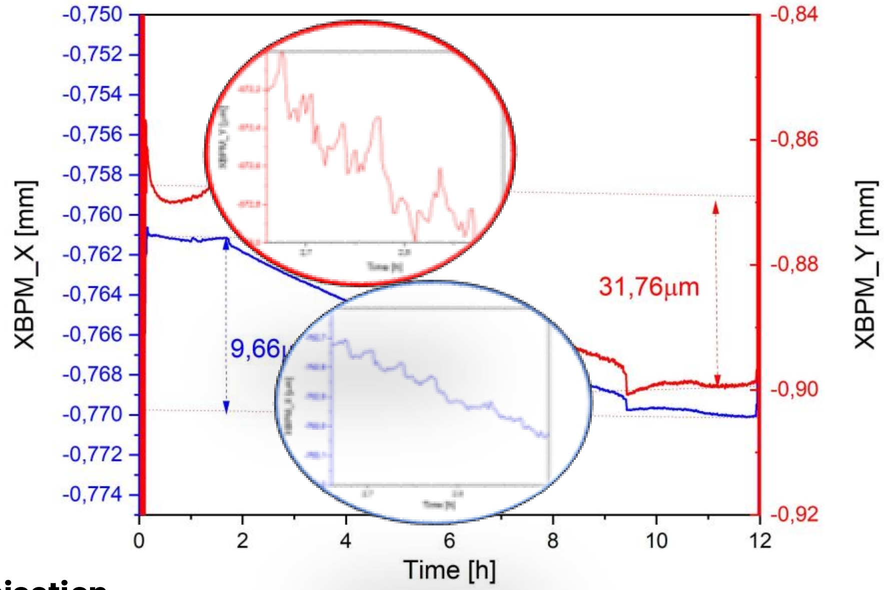
- Measurements of the flow in main water circuits and opti… d the problem.

Closed Orbit Stability & Repeatability

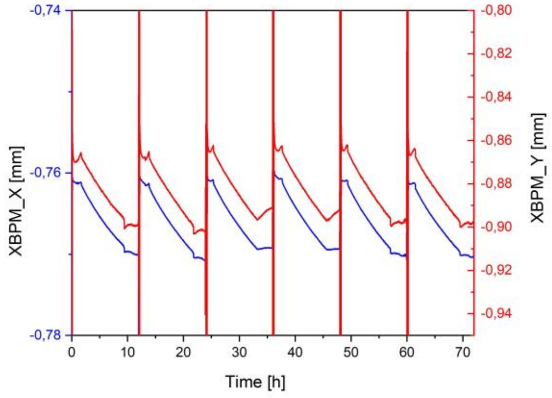
Electron beam stability in the sub-micrometer level

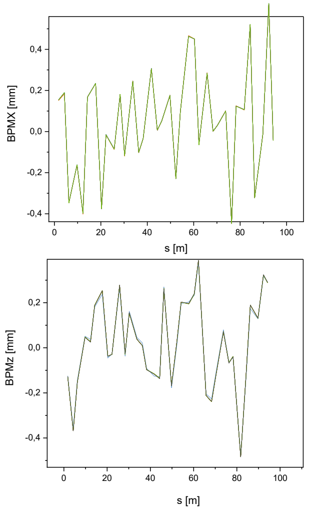


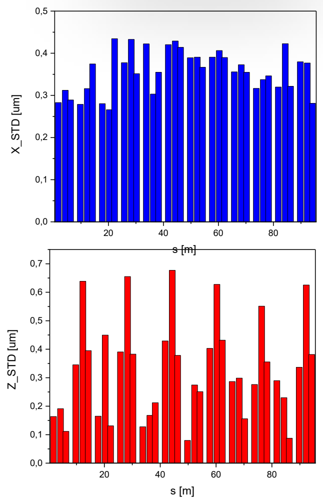
Long and short-term stability of the photon beam



Repeatability of the injection

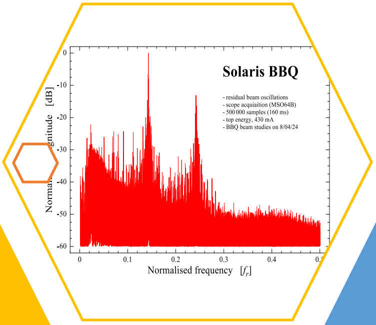






- ❖ Submicron precision in electron beam stability was achieved
- ❖ Beam position reproducibility is at a good level, but some thermal drift remains in the XBPM readouts.

Beam Diagnostics Development

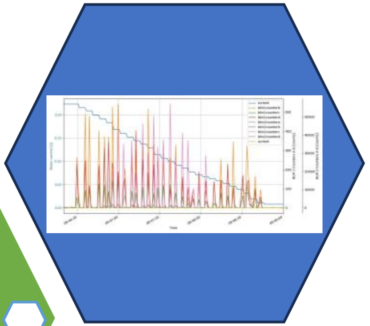


Future plans for self adjusting ID correction table: Automation of the construction and updating of feed forward correction tables for insertion devices (IDs)

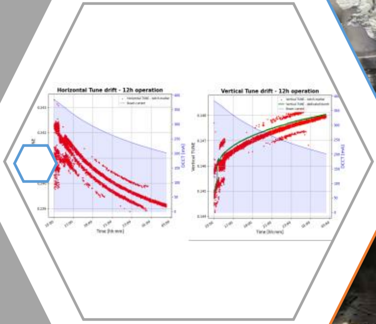
Tune Feedback: An automatic tune correction system based on online tune measurements and magnets adjustment in storage ring during ID operation.

Beam loss monitor signal anomaly detection : Detection of statistical deviations in signals from beam loss monitors (BLM)

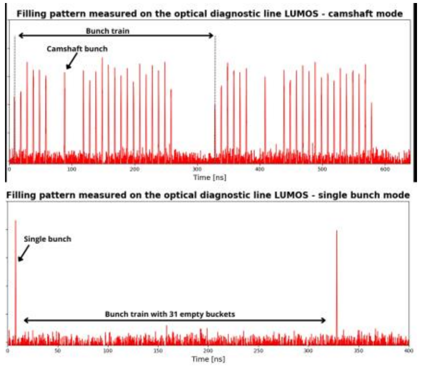
Demo GUI based on Taranta BLM & RAD stations: The visual representation of beam loss detectors and radiation measuring stations placement around storage ring, as well as counter readings and interlock state from every BLM device.



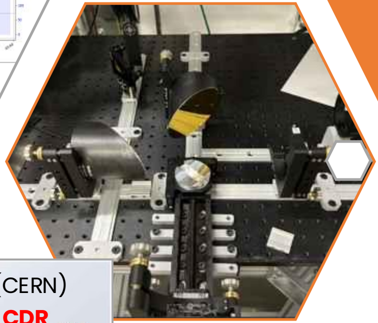
Bunch by bunch feedback system implementation and operation as diagnostic tool for tune measurements, bunch cleaning, transverse beam instabilities suppression etc.

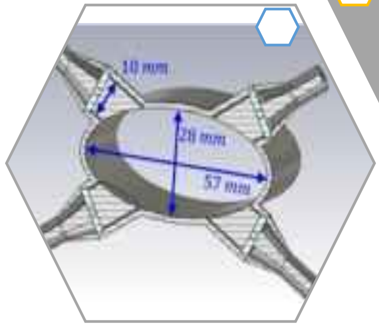


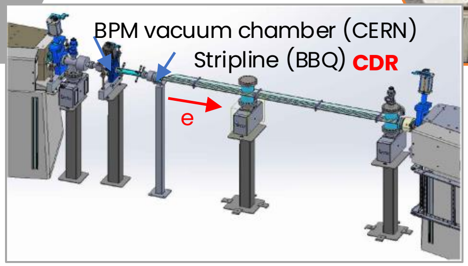
Diagnostics of the longitudinal electron beam profile for PolFel: A Martin–Puplett interferometer configuration for Coherent Diffraction Radiation (CDR) signal analysis.



BPM for FCCee (CERN) NCPS. In addition to operating a prototype **Base Band Tune (BBQ)** system, Solaris will also test **Beam Position Monitors (BPM)** to support the development of next generation accelerator instrumentation.



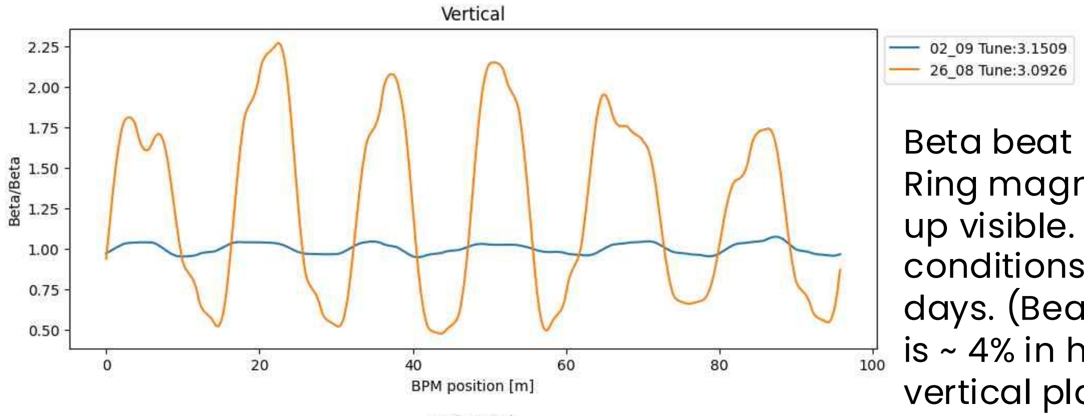


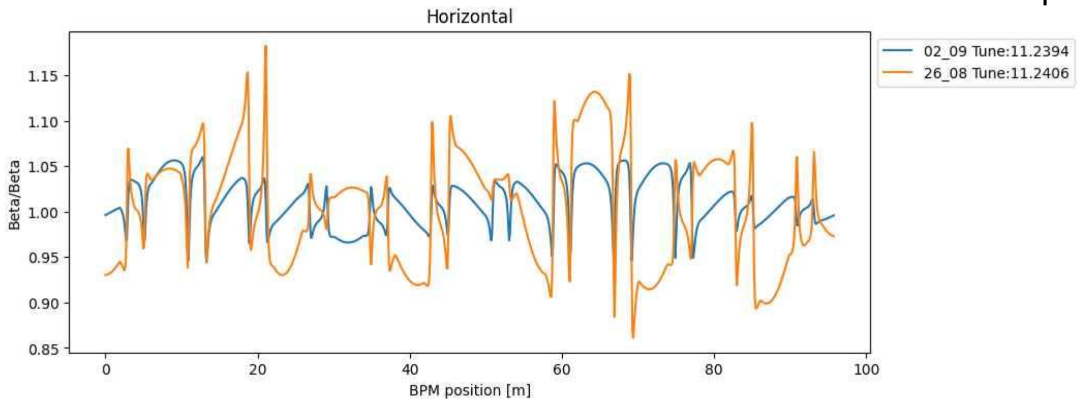


Beam Diagnostics – machine state study

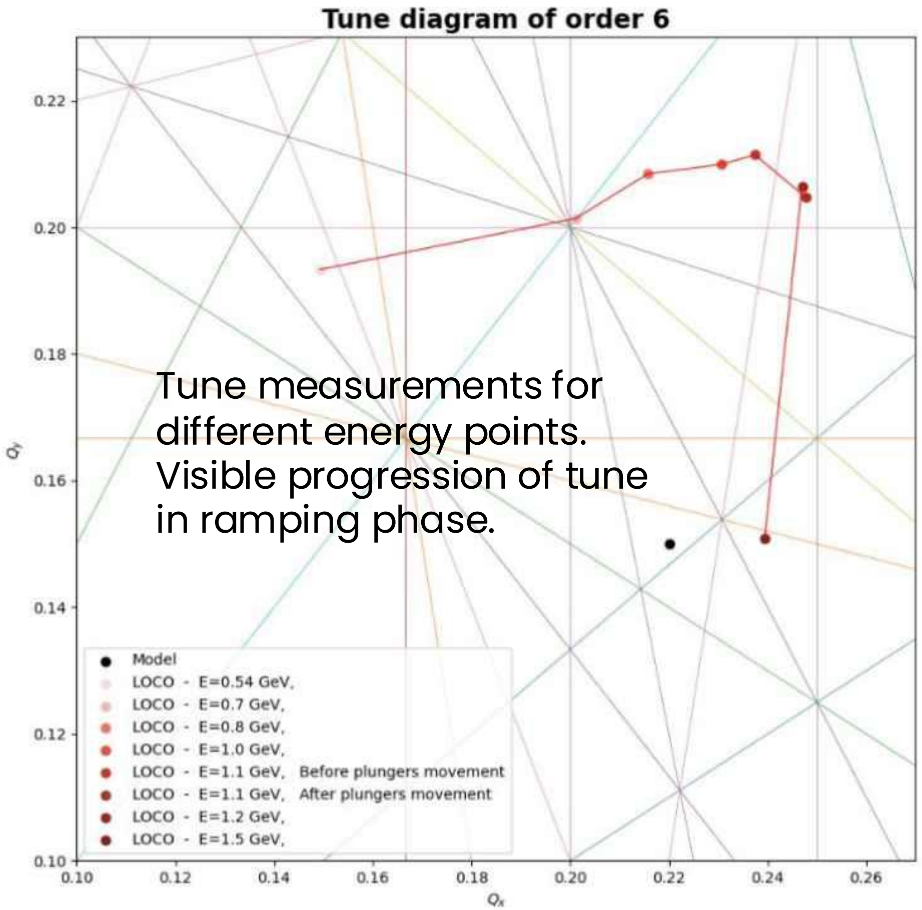
Periodic LOCO (**L**inear **O**ptics for **C**losed **O**rbits) measurements after machine shutdown:

- Response matrix measurements
- Dispersion measurements
- Tune measurements
- Quadrupole field gradient measurements



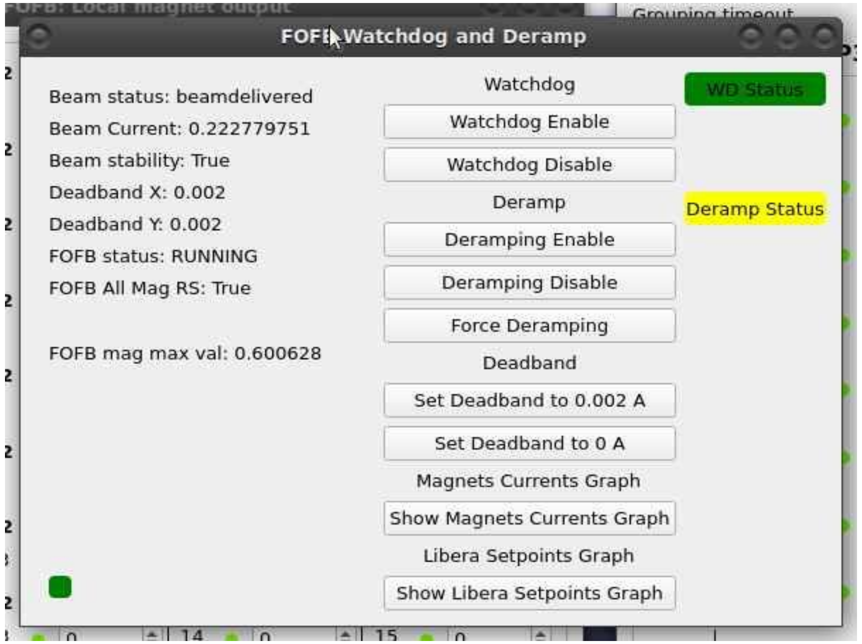


Beta beat measurements. Ring magnetic lattice warm up visible. Operational conditions achieved after 10 days. (Beating after warm up is ~ 4% in horizontal and vertical plane)

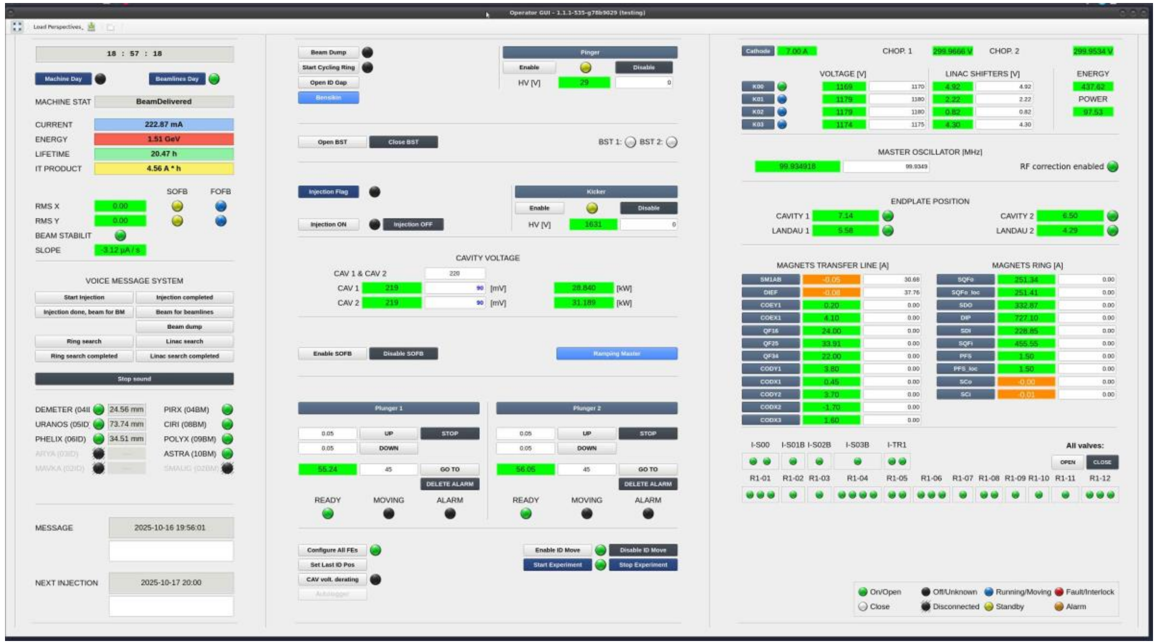


Tune measurements for different energy points. Visible progression of tune in ramping phase.

New CR scripts

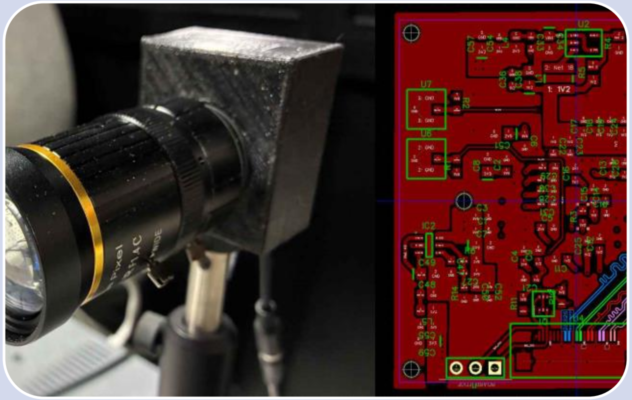


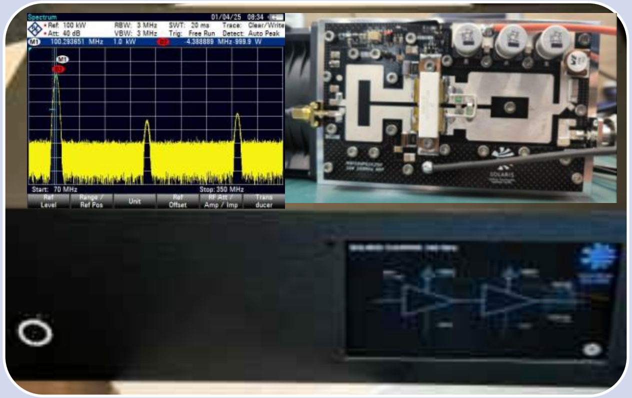
Watchdog for fast corrector magnet de-ramping in case of current saturation.



All in one, streamlined operator GUI for faster problem diagnostic and simpler injection/dump procedure.

Electronics Development





Color 12 and 20 Mpix cameras project with CSI-2 interface

Our design is based on Sony IMX477 and IMX283 sensors. Except the standard Raspberry HQ Camera features our version has external hardware trigger that triggers directly the sensor without any intermediate processing. Both of the cameras has three power supplies. Digital part is supplied from TLV62568 DC/DC converter and analog and I/O part are supplied from low noise TPS79301 LDOs. Both cameras has 4-lane MIPI interface used for video streaming.

Ring magnets voltage drops monitoring in each section

For Magnets and power supply section we designed 16-channel, precision differential voltage measurement device. Prototype is used in R01 section, but device is designed to communicate wirelessly with other devices to gather data. Each magnet in each bending section can be monitored for potential damages i.e. too high voltage drop. Measurements can be corelated with other machine data.

New 100 MHz 1 kW RF chopper

Once chopper made by MAX IV need to be repaired, a decision was taken to build our own design. Main requirements:

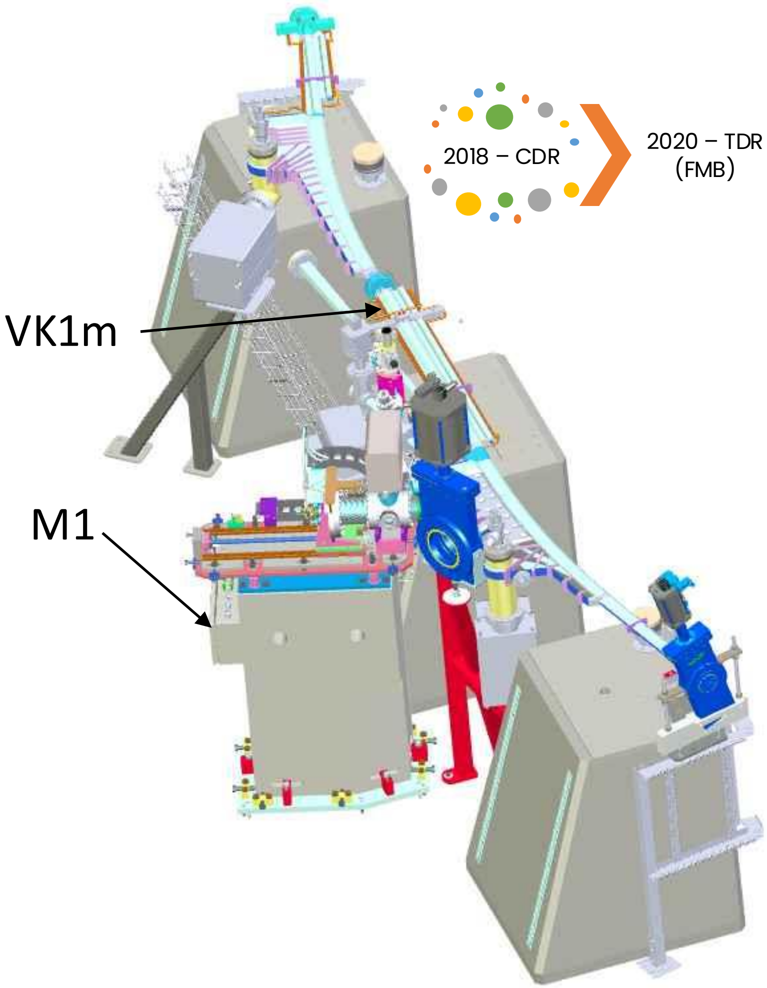
- RF transistor in power stage same as used in Storage Ring power amplifiers
- one to one replacement of currently used
- pulse forward and reflected power stable readings
- current monitoring for driver and final stage transistors
- well documented whole design process (PCB Gerber files, mechanical drawings, firmware)

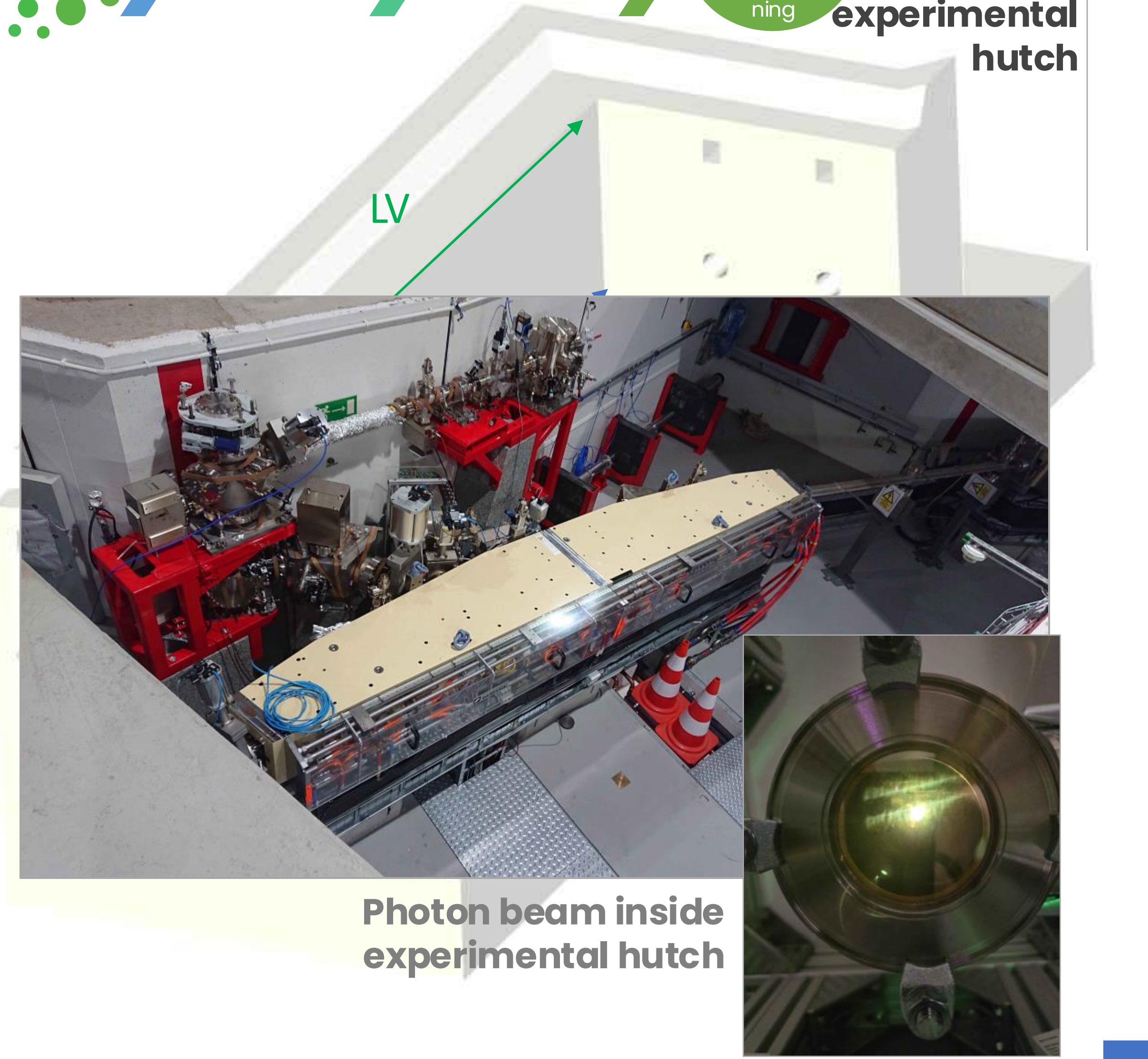
New Beamlines Development: CIRI

Installation and Commissioning of the CIRI Beamline

2018 – CDR › 2020 – TDR (FMB) › 2021 – Manufacture (FMB) › 2023 – Installation & Commissioning

2021 – CDR › 2022 – TDR (SOLARIS) › 2023 – Manufacture › 2024 – Installation & Commissioning





experimental hutch

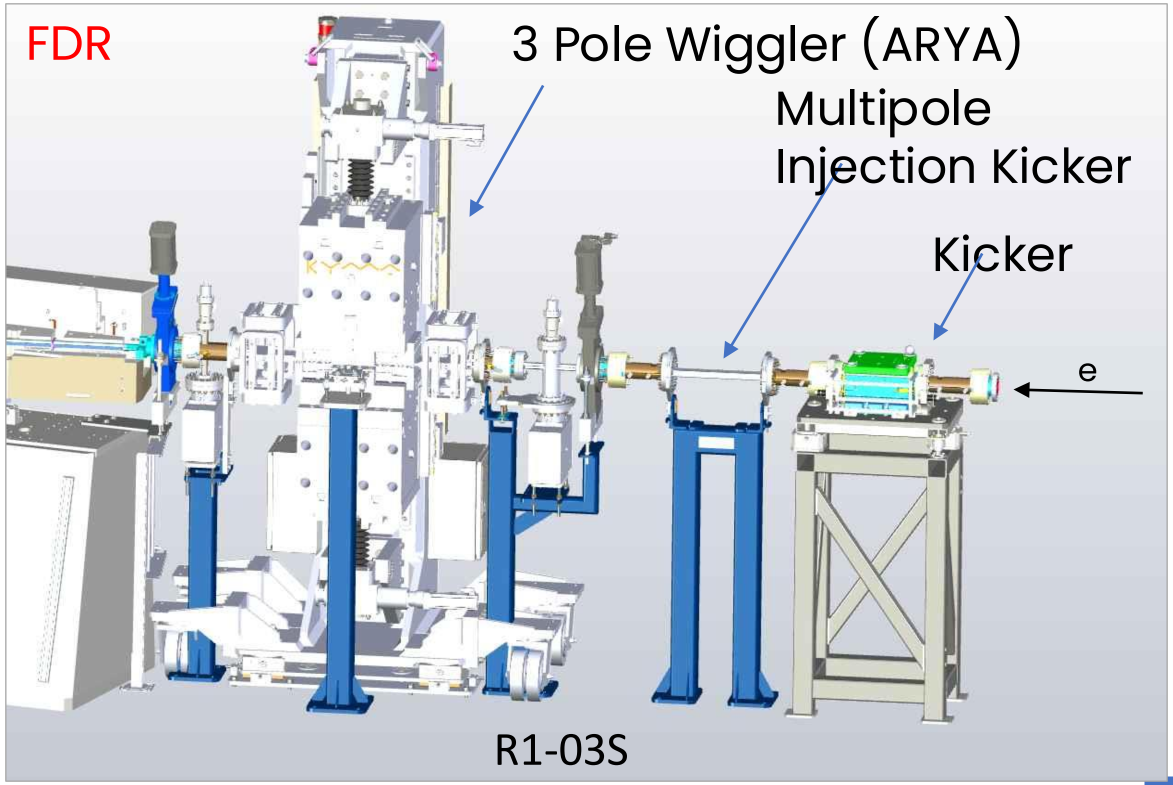
Photon beam inside experimental hutch

New Beamlines Development: ARYA

Technical Design Report of ARYA Beamline

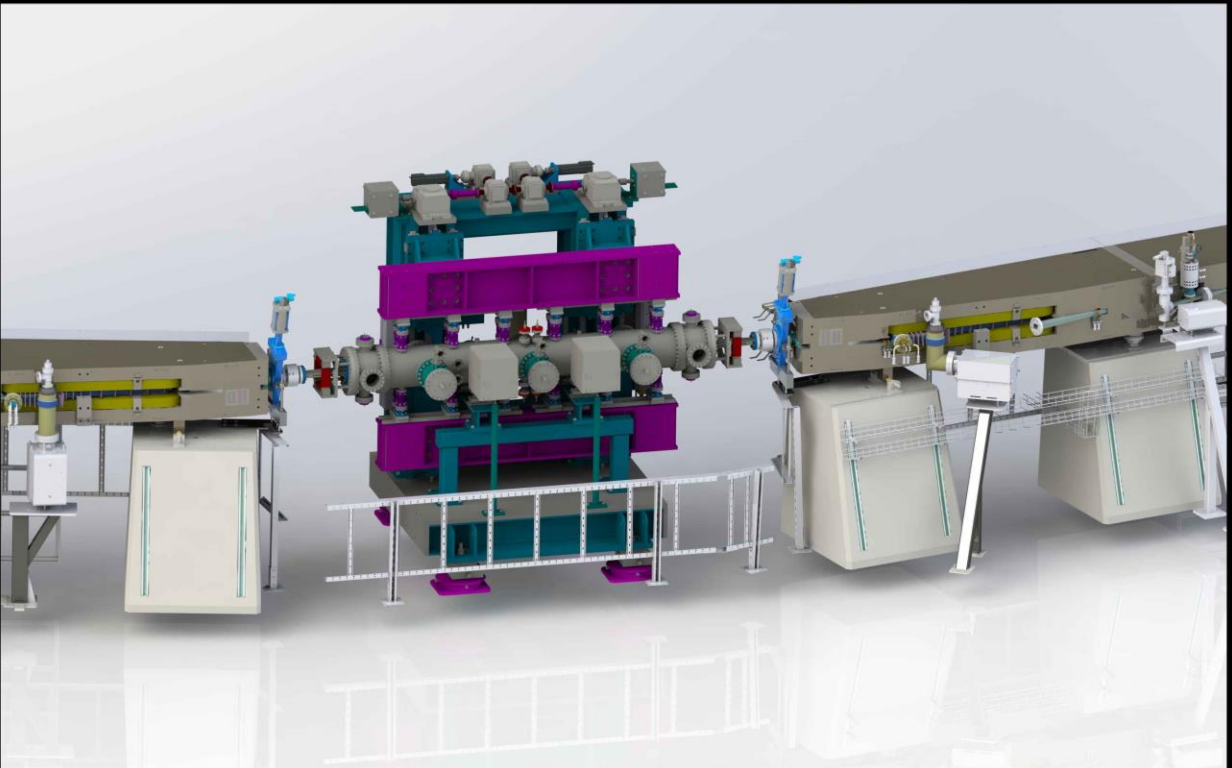
Saga of ARYA…

- 2019 – Superconducting Wiggler SCW (Budker Institute of Nuclear Physics)
- 2021 – SCW - Design Study (FMB) modification of the storage ring
- 2022 – SCW – Final Design Report (Budker Institute of Nuclear Physics)
- 2023 – New source 3 Pole Wiggler (3PW) from KYMA ordered
- 2023 – 3PW - Design Study (FMB) modification of the storage ring straight section
- 2024 – Straight section Conceptual Design Report (CDR)
- 2025 – Delivery of the 3PW (KYMA) Straight Section Preliminary Design Review (PDR)
- 2025 – Straight section (FMB) Final Design Review (FDR)
- 2026 – FAT, SAT, Delivery of straight section components



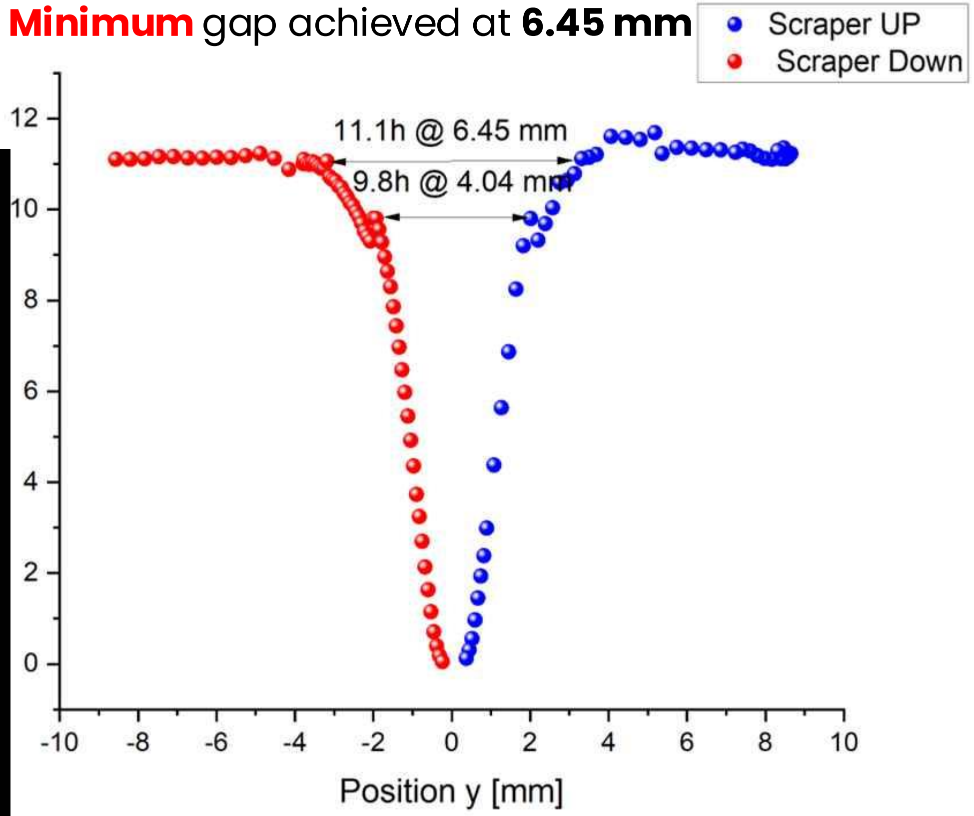
New Beamlines Development: MAVKA

MAVKA is a in vacuum horizontal undulator, it will be installed in the middle of the 2nd strait section.
Total magnetic length: 1.824 m
Mo [redacted]
Pe [redacted]



In beam test:
Mimicking MAVKA aperture with upper and lower vertical scraper. Test was done for ~ 400 mA beam current

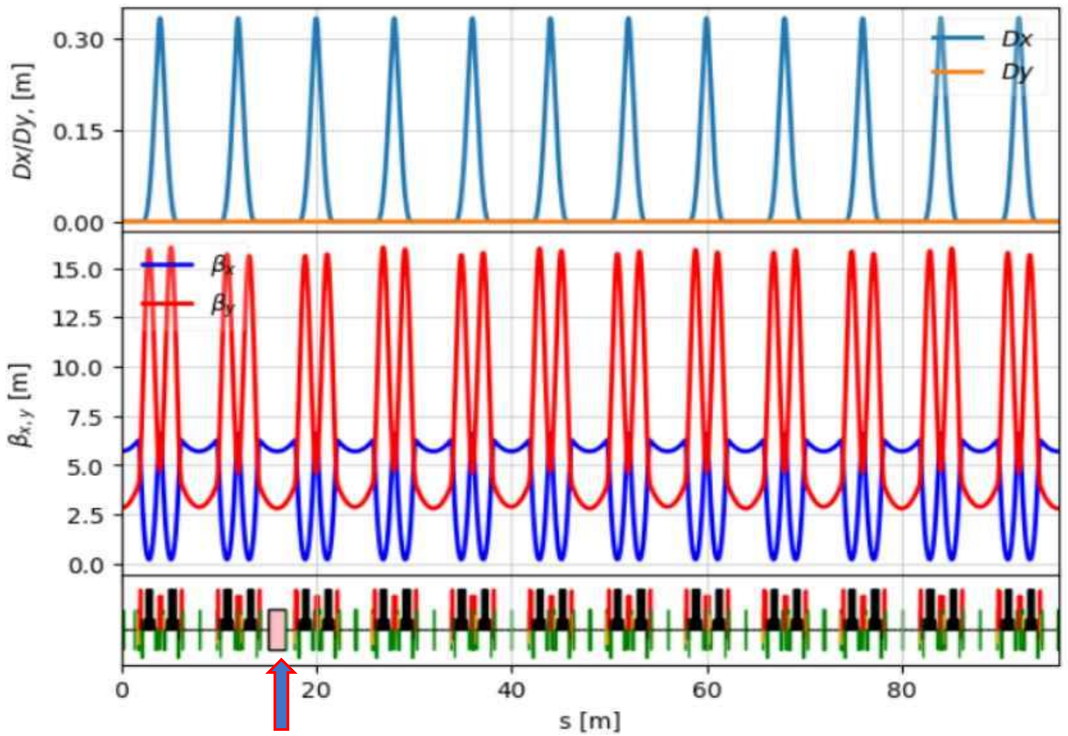
Minimum gap achieved at **6.45 mm**



[redacted]eld induced on scraper introduces beam instabilities [redacted]ing Tauschek effect. This corresponds to continues [redacted]ifetime degradation.

New Beamlines Development: MAVKA

MAVKA is a in vacuum horizontal undulator, it will be installed in the middle of the 2nd strait section.
Total magnetic length: 1.824 m
Maximum field: 0.9 T at 4.75 mm gap
Periods: 96
Period length: 0.019 m



	Bx/y entrance [m]	Bx/y mid ID [m]	Bx/y exit [m]
Model lattice	beta_x = 5.61 beta_y = 3.13	beta_x = 5.46 beta_y = 2.84	beta_x = 5.61 beta_y = 3.13
Actual measured	beta_x = 5.94 beta_y = 2.95	beta_x = 5.84 beta_y = 2.75	beta_x = 5.98 beta_y = 3.08
Model with Mavka Ocelot	beta_x = 5.61 beta_y = 3.08	beta_x = 5.46 beta_y = 2.80	beta_x = 5.61 beta_y = 3.08

Slight vertical focusing coming from undulator visible (Wakefield not included in calculations)

New Beamlines Development

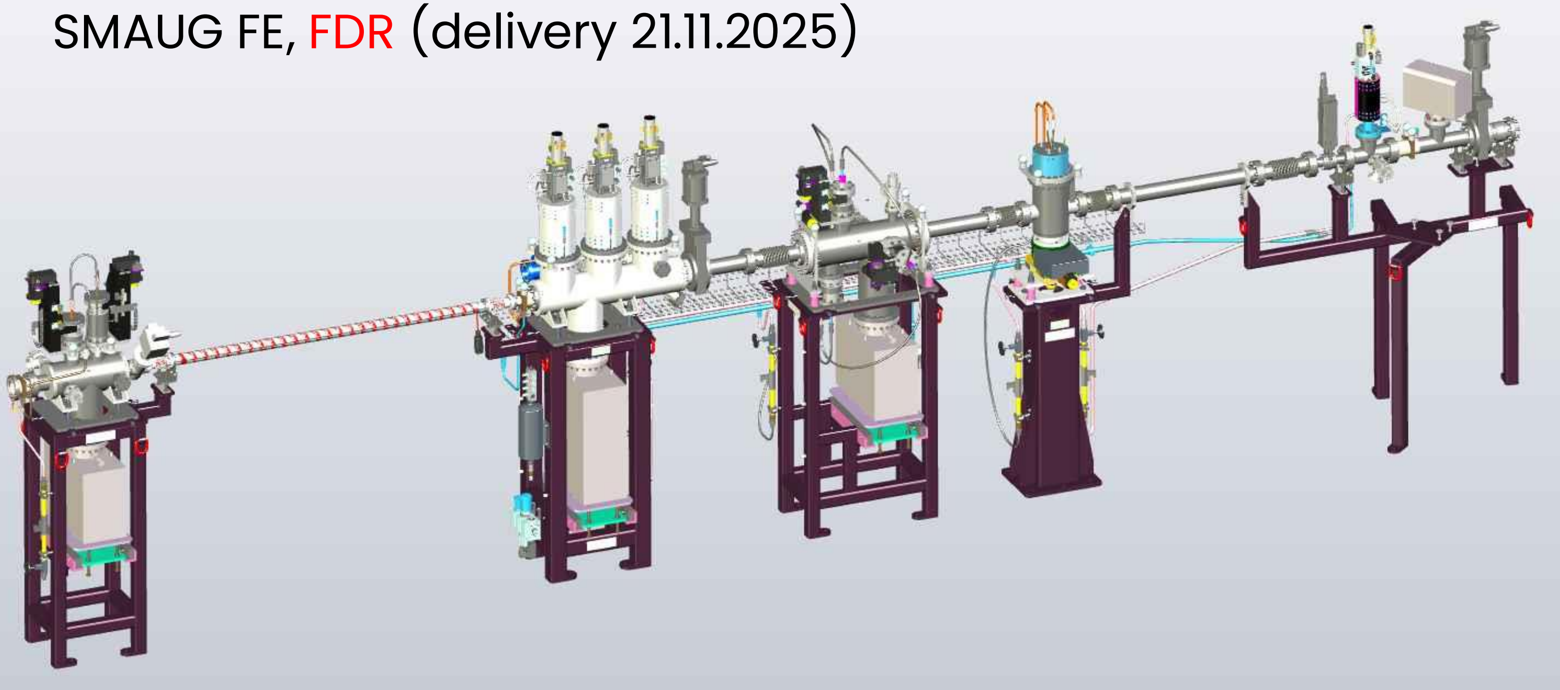
ARYA – Front End & Beamline design

SMAUG – Front end & Beamline design

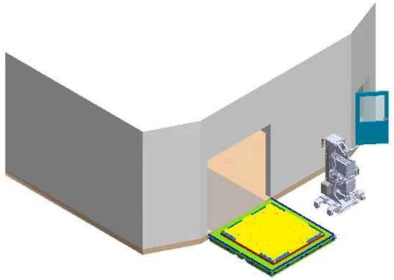
PHELIX – 2nd Branch design

MAVKA – Insertion device (IVU), straight section, front end design

SMAUG FE, FDR (delivery 21.11.2025)



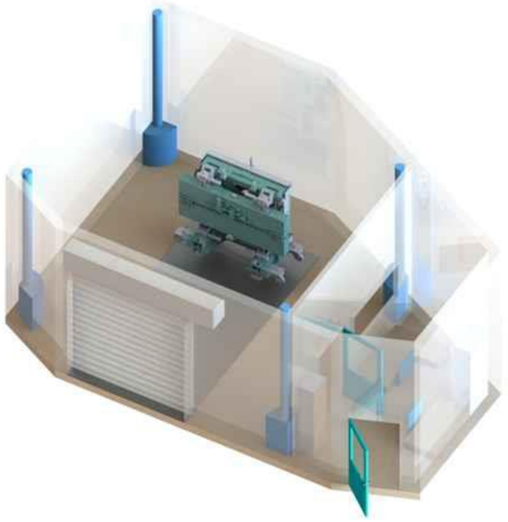
Development of Magnetic Lab



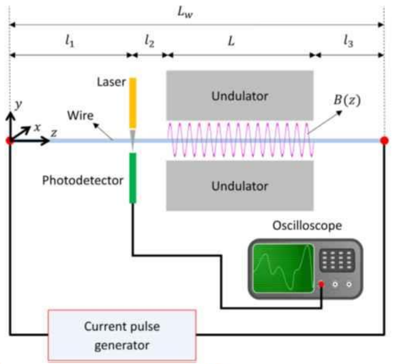
- **Construction of the magnetic laboratory (in progress)**
- Adaptation of the available space after removal of the CrioTEM microscope: additior resin surface on the floor, reinforcement of the main communication path for hea equipment, refreshment of the walls,

- **Construction of the measuring systems for magnetic measurements (in progress)**
- Wide spectrum of measurements are foreseen inside the magnetic laboratory:
  - o Rotating coil measurements
  - o Stretched wire measurements
  - o Vibrating wire measurements
  - o Hall probe measurements

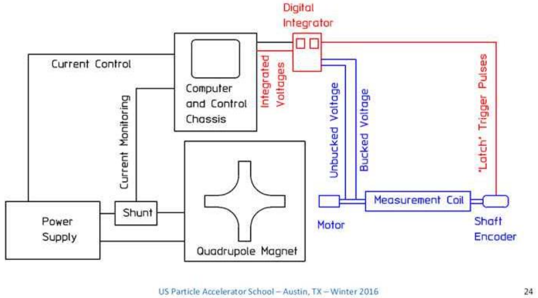
  All measurements are intended to strengthen Solaris' operational capabilities and lead to reduction of the production costs and, in extreme cases, to the independence of external suppliers.



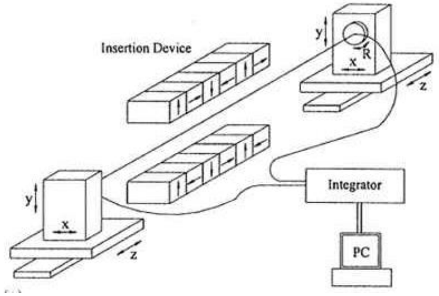
pulsed wire system



rotating coil system

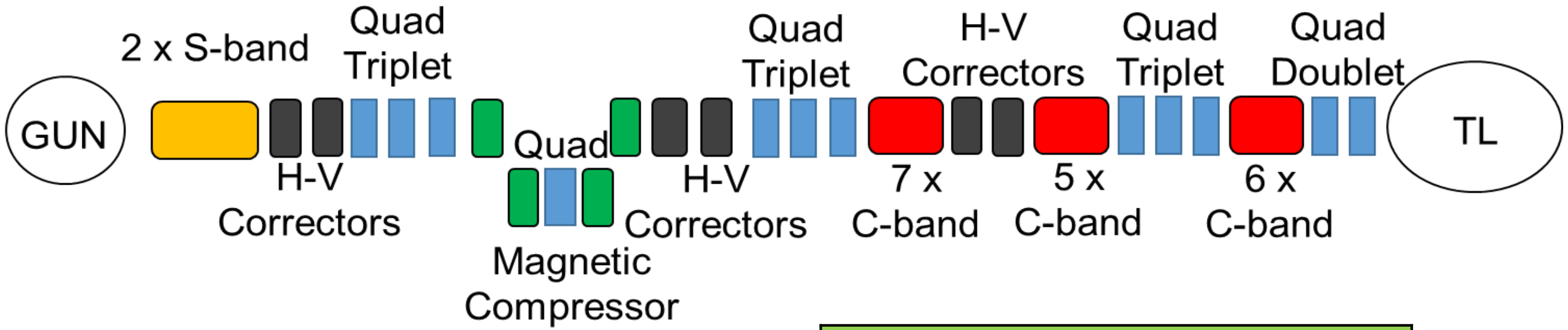


Stretched wire system



Upgrade plan for LINAC

- Hybrid S-band/C-band LINAC with magnetic bunch compressor
- Barium oxide thermionic cathode gun and additional laser photocathode gun
- Top-up operation, injections every few minutes
- 2 x S-band and 18 x C-band RF structures
- Optics simulations done in Elegant, PyAT and Astra for early stages of acceleration

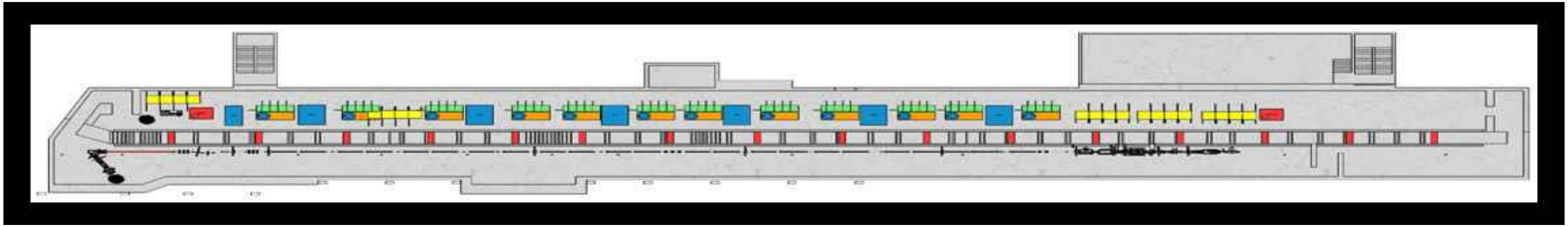


Parameters of new Linac	
Energy [GeV]	1.5
Accelerating Gradient [MV/m]	50
RF Frequence [MHz]	5712
Bunch charge [nC]	0.2
Hor. Emittance [mm mrad]	1.69
Ver. Emittance [mm mrad]	1.43
Rep. rate [Hz]	10
Bunch lenght on exit [ps]	0.48
Length [m]	67
Energy spread [keV]	794

Parameters of bunch compressor	
Energy [GeV]	0.225
Lenght (with drifts) [m]	2.54
Lenght (single dipole) [m]	0.3
Compression rate	3.373
Deflection angle (single dipole) [rad]	0.198
Bending field (single dipole) [T]	0.496
Radius of curvature (single dipole) [m]	1.515
R56 [m]	-0.048
Bunch lenght on entrance [ps]	1.69

Challenges

- The size of the tunnel is fixed and space is limited it can be demanding to fit all equipment in technological tunnel



- Laser lab for the photocathode gun need to be established
- Injection scheme with multipole kicker need to be optimised
- Radiation protection shielding and beam dump need to be calculated and verified
- Although the infrastructure (cooling and electricity) demands are fulfilled, there could be a need to develop new secondary cooling units, or liquid nitrogen cooling linac technology
- Developing LLRF system for linac
- For the future FEL or SPF the linac tunnel need to be expanded and experimental area need to be foreseen.

SUMMARY

Supporting operation and improving beam stability. High availability.

Diagnostics development :

FOFB, BBFB, BLM, Tune FB and BPM system for SOLARIS I FCC ee.

New beamlines development (CIRI, ARYA, SMAUG, MAVKA) and installation

Magnet Lab development including magnet diagnostic tools (stability, alignment), ID development

Full energy linac development

Acknowledgements

All SOLARIS TEAM

MAX IV TEAM

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Dmytro Butt, Rober Nietubyć (NCBJ - POLFEL)

PSI TEAM (Magnet Group, MAVKA BL team)

CERN

dimtel

INFN

polfel

PAUL SCHERRER INSTITUT PSI

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Thank you for your attention!

THE LORD OF THE RINGS
THE FELLOWSHIP OF THE RING