JAGIELLONIAN UNIVERSITY
IN KRAKÓW

SOLARIS
NATIONAL SYNCHROTRON
RADIATION CENTRE

SOLARIS operation & upgrade status, economy plan

Adriana Wawrzyniak
On behalf of SOLARIS TEAM

Grenoble, 14-15.12.2022

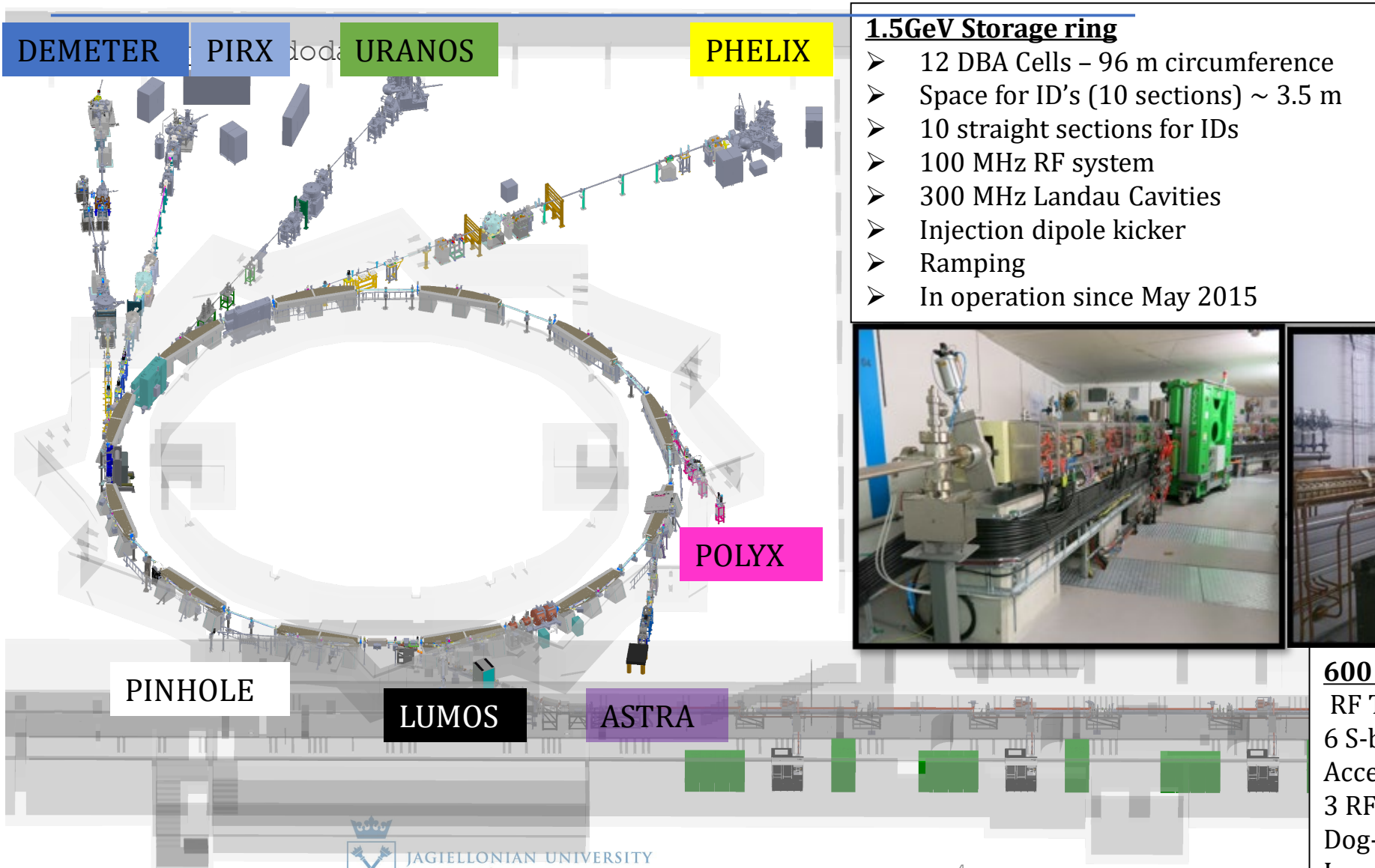
SOLARIS National Synchrotron Research Centre

European Synchrotron Light Sources Workshop, ESRF, Grenoble

OVERVIEW

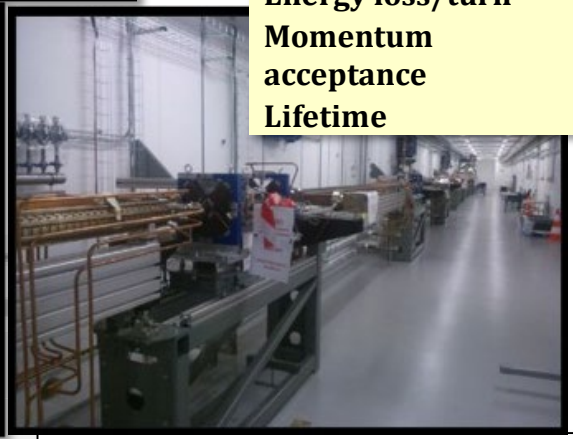

Jagiellonian University New Campus
Kraków City Center
SOLARIS

ACCELERATORS



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



Parameter	Designed
Energy	1.5 GeV
Max. current	500 mA
Harmonic number	32
Natural emittance	6 nmrad
Coupling	1 %
Tune ν_x, ν_y	11.22, 3.15
Corrected chromaticity ξ_x, ξ_y	+2,+2
Energy loss/turn	114.1 keV
Momentum acceptance	4%
Lifetime	13h

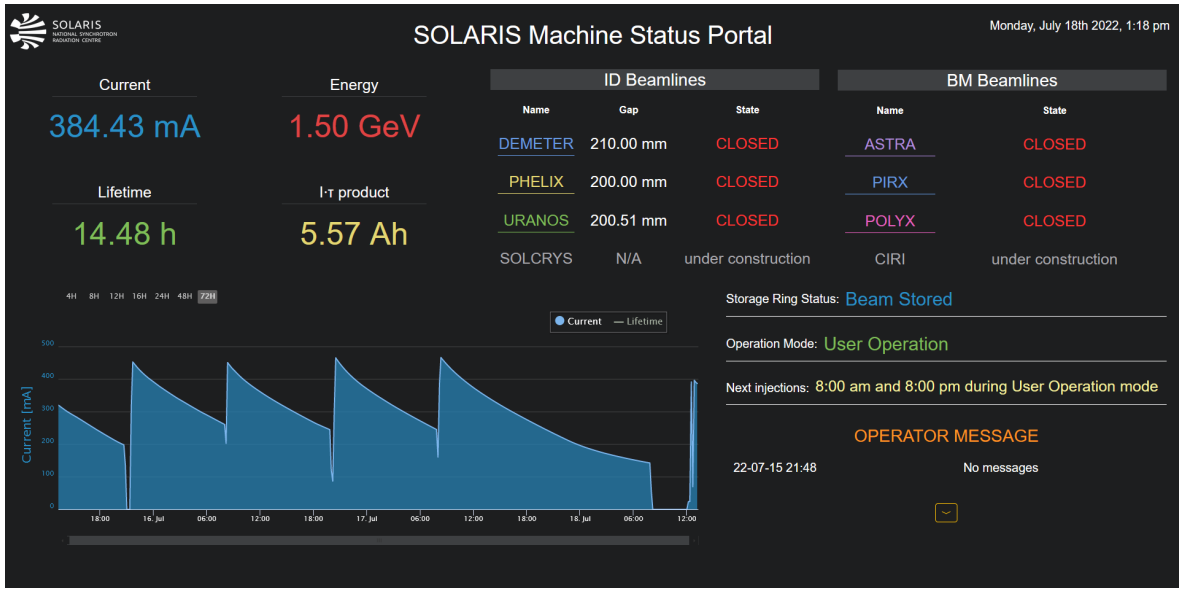
600 MeV Linac

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

SOLARIS STATISTICS

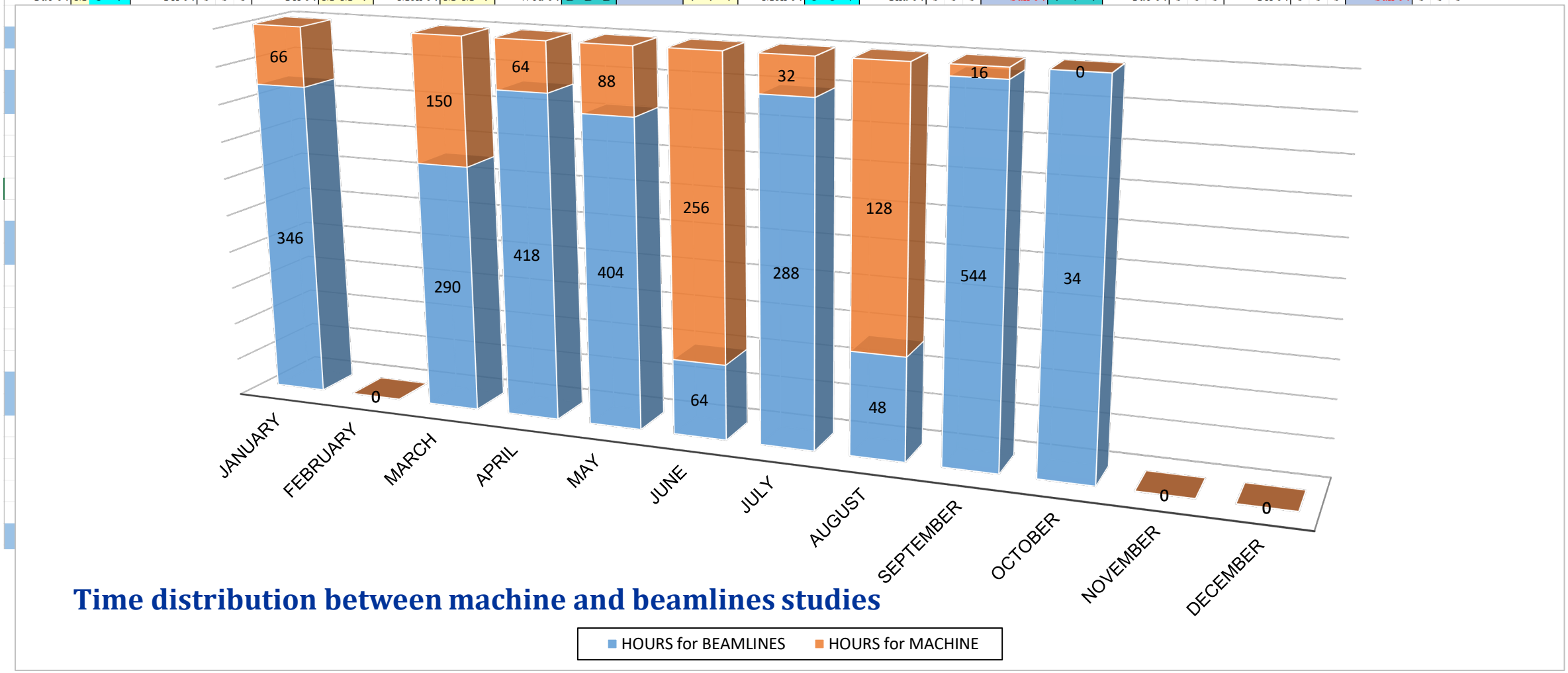
SOLARIS OPERATION

- 2 Shifts from Monday to Saturday (8:00-16:00; 14:00-22:00)
- On call support to 2:00 am from Tuesday-Saturday
- 2operators/shift
- Monday – machine days, maintenance
- User operation 5 days/week (Tue-Sat)
- Sunday – no injection, or injection upon request
- Injection twice/day: 8:00 am and 8 pm
- One operation mode (uniform filling pattern)
- Operation in the decay mode

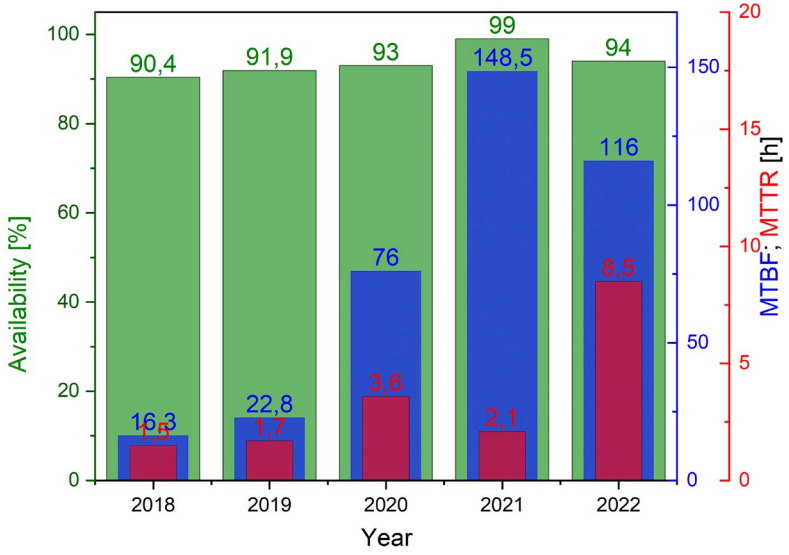


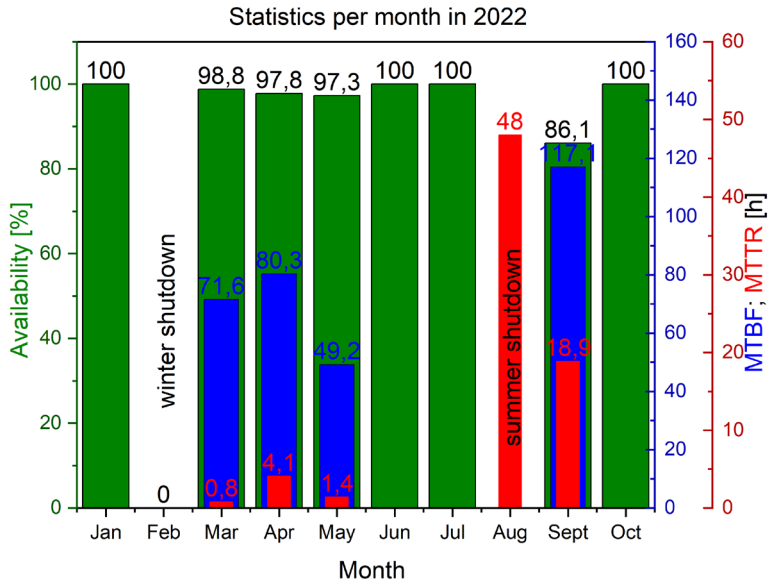
OPERATION IN 2022

Jan 2022				Feb 2022				Mar 2022				Apr 2022				May 2022				Jun 2022				Jul 2022				Aug 2022				Sep 2022				Oct 2022				Nov 2022				Dec 2022			
Sat 01	s	s	s	Tue 01	s	s	s	Tue 01	O	.	.	Fri 01	B	B	B	Sun 01	.	.	.	Wed 01	M	M	.	Fri 01	C	C	.	Mon 01	s	s	s	Thu 01	B	B	B	Sat 01	B	B	B	Tue 01	s	s	s	Thu 01	s	s	s
Sun 02	s	s	s	Wed 02	s	s	s	Wed 02	O	.	.	Sat 02	B	B	B	Mon 02	M	M	.	Thu 02	M	M	.	Sat 02	.	.	.	Tue 02	s	s	s	Fri 02	B	B	B	Sun 02	.	.	.	Wed 02	s	s	s	Fri 02	s	s	s
Mon 03	O	.	.	Thu 03	s	s	s	Thu 03	M	M	.	Sun 03	.	.	.	Tue 03	.	.	.	Fri 03	M	M	.	Sun 03	.	.	.	Wed 03	s	s	s	Sat 03	B	B	B	Mon 03	s	s	s	Thu 03	s	s	s	Sat 03	s	s	s
Tue 04	M	C	.	Fri 04	s	s	s	Fri 04	M	M	.	Mon 04	M	M	.	Wed 04	B	B	B	Sat 04	.	.	.	Mon 04	C	C	.	Thu 04	s	s	s	Sun 04	.	.	.	Tue 04	s	s	s	Fri 04	s	s	s	Sun 04	s	s	s

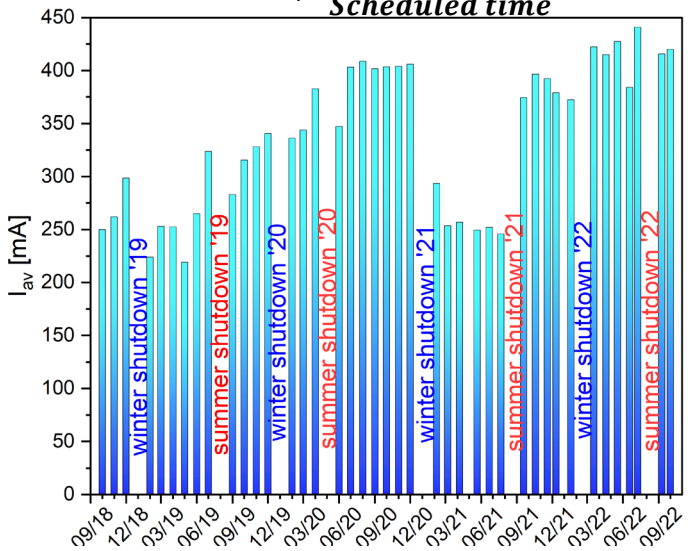


AVERAGE CURRENT DELIVERED

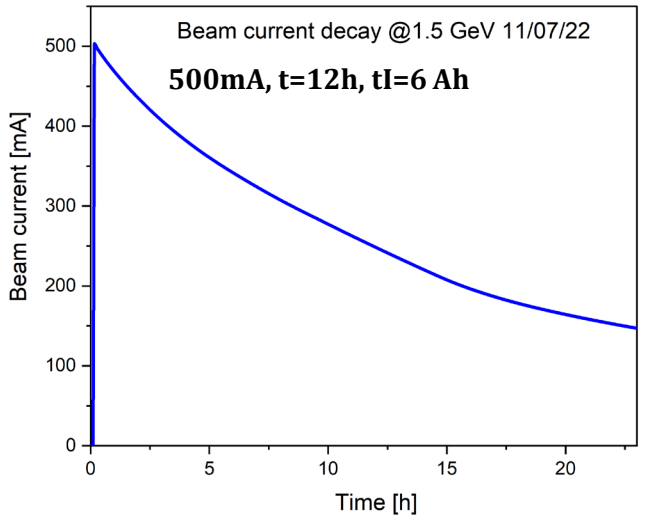




Availability=$\frac{\textit{Delivered time}}{\textit{Scheduled time}}$

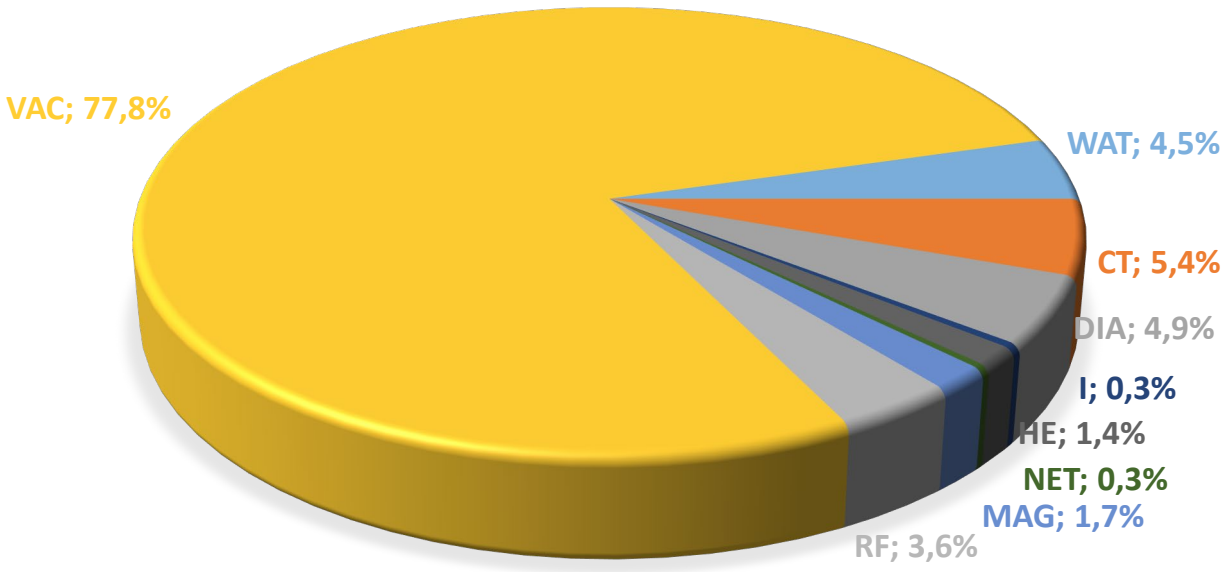


Year	Total Beamtime	Availability	MTBF	MTTR	Average current
2018	1704 h	90.4 %	16.3 h	1.5 h	270 mA
2019	2530 h	91.9 %	22.8 h	1.7 h	284 mA
2020	3868 h	93.0 %	76.0 h	3.6 h	385 mA
2021	4654 h	99.0 %	168.7 h	2.2 h	302 mA
2022	**3236 h**	**94.0%**	**116.0 h**	**8.5 h**	**411 mA**

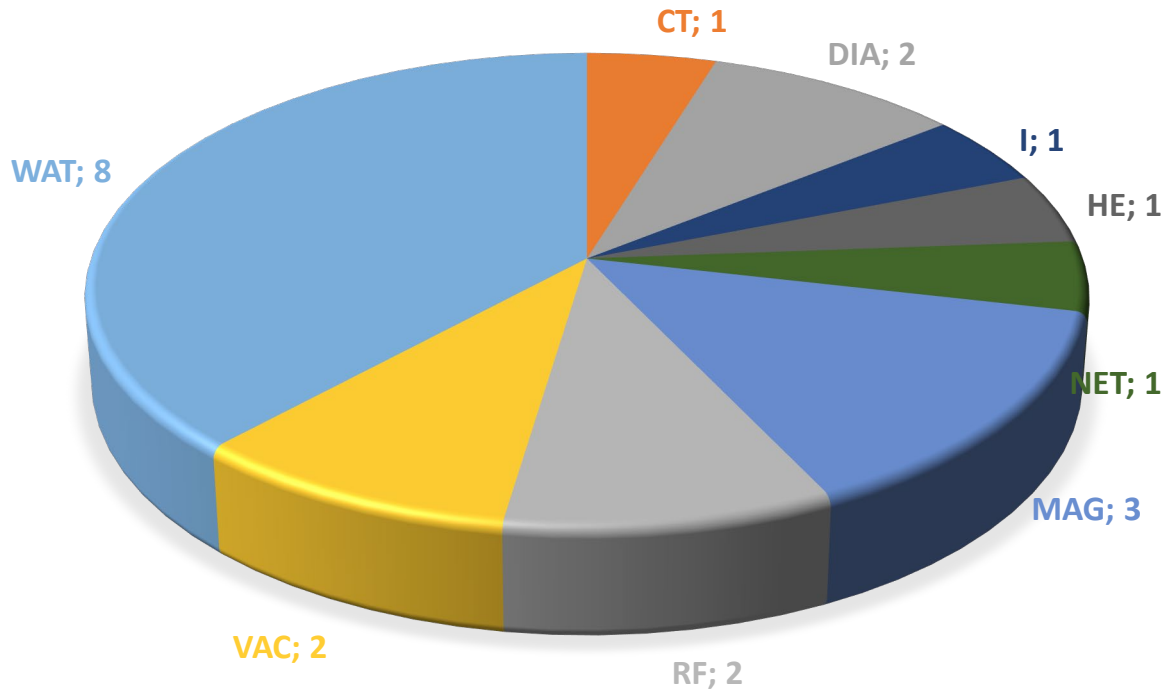


FAILURE STATISTICS

Failures by time

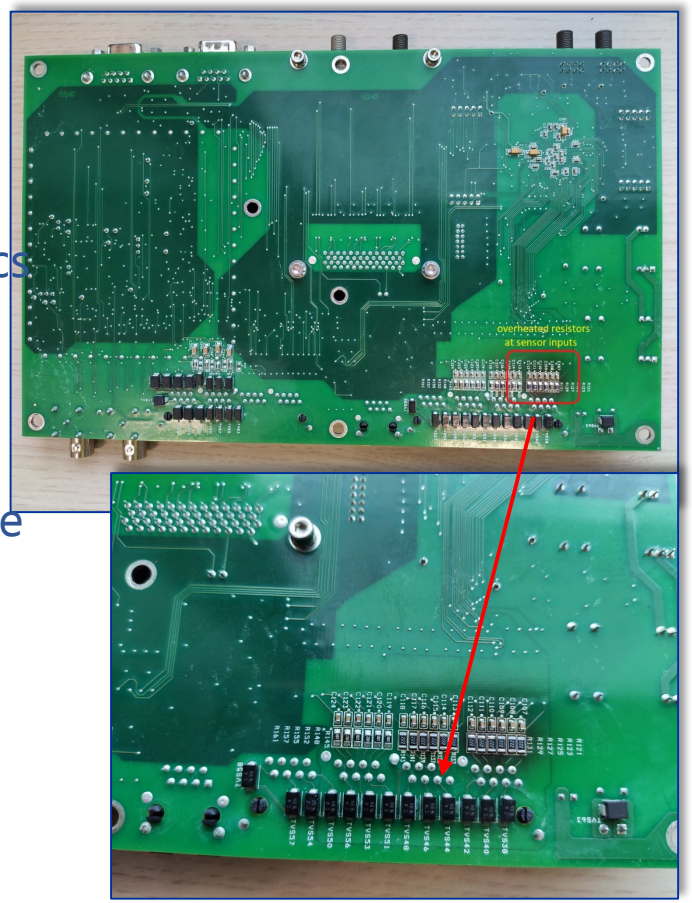


Failures by number



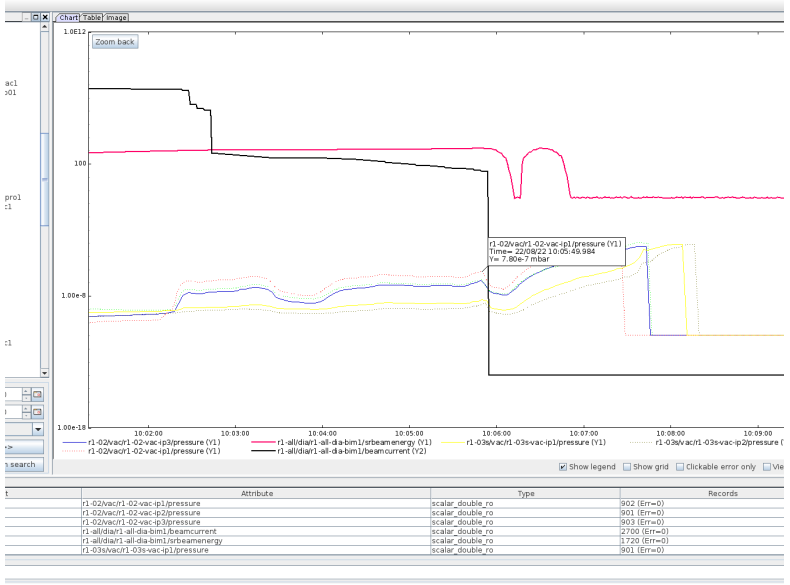
MAIN FAILURES

- Problem with communication with Tango Host (8h)
- Problem with coding water – flow switches interlocks
- Modulators failures (Interlocks (overheating) on the K00 modulator, diagnostics showed that the resistors used by the manufacturer have too little power (was: 125mW, should be 250mW- replaced) Series of problems with the K03 modulator, IGBT modules fail and power supply for IGBT– replacement; upgrade firmware and set „Index address" was needed)
- Thermocouples failure
- Injector – phase shifter failure
- Power supplies problems- interlocks and communication with TANGO
- Vacuum chamber failure



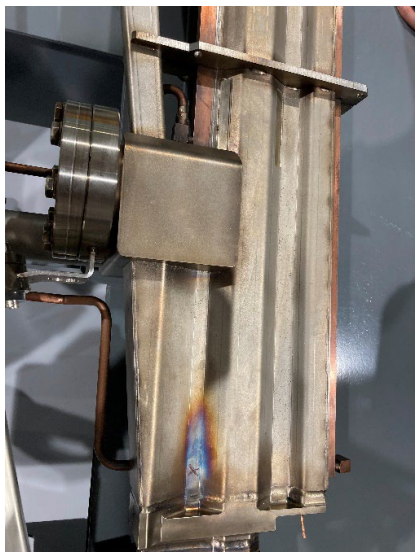
VACUUM CHAMBER FAILURE

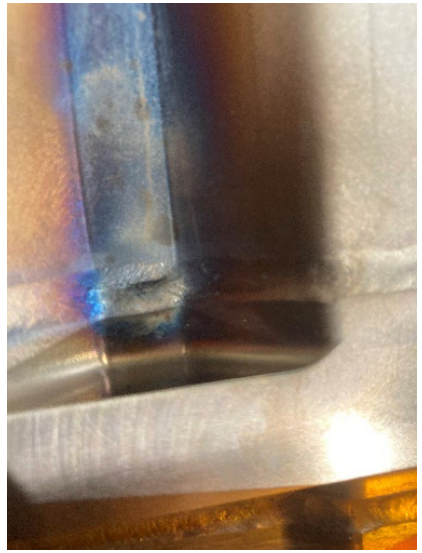
22.08.22 during ramping the vacuum chamber installed in DBA02 was demaged and vacuum leak was observed.
The diagnostics, new vacuum installation and **get back to operation** took **5 days.**
Quick restart was possible due to **spare vacuum chamber ready for installation.**

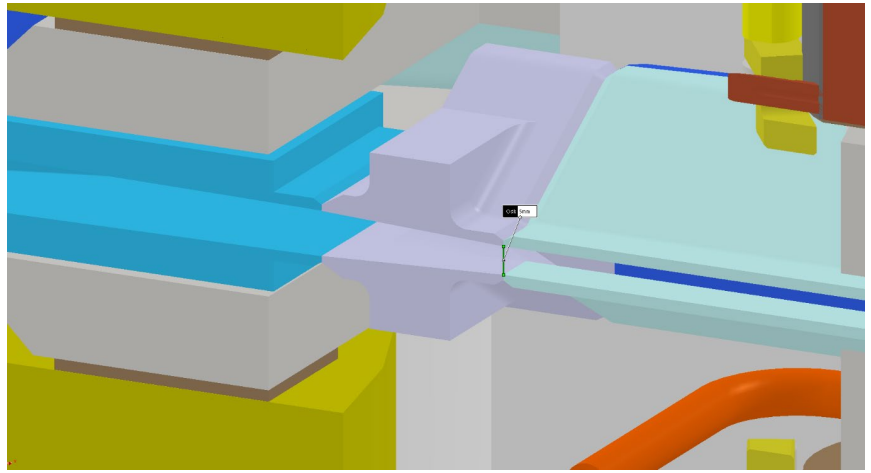


pressure increase observed during the failure

Visible damage to the vacuum chamber



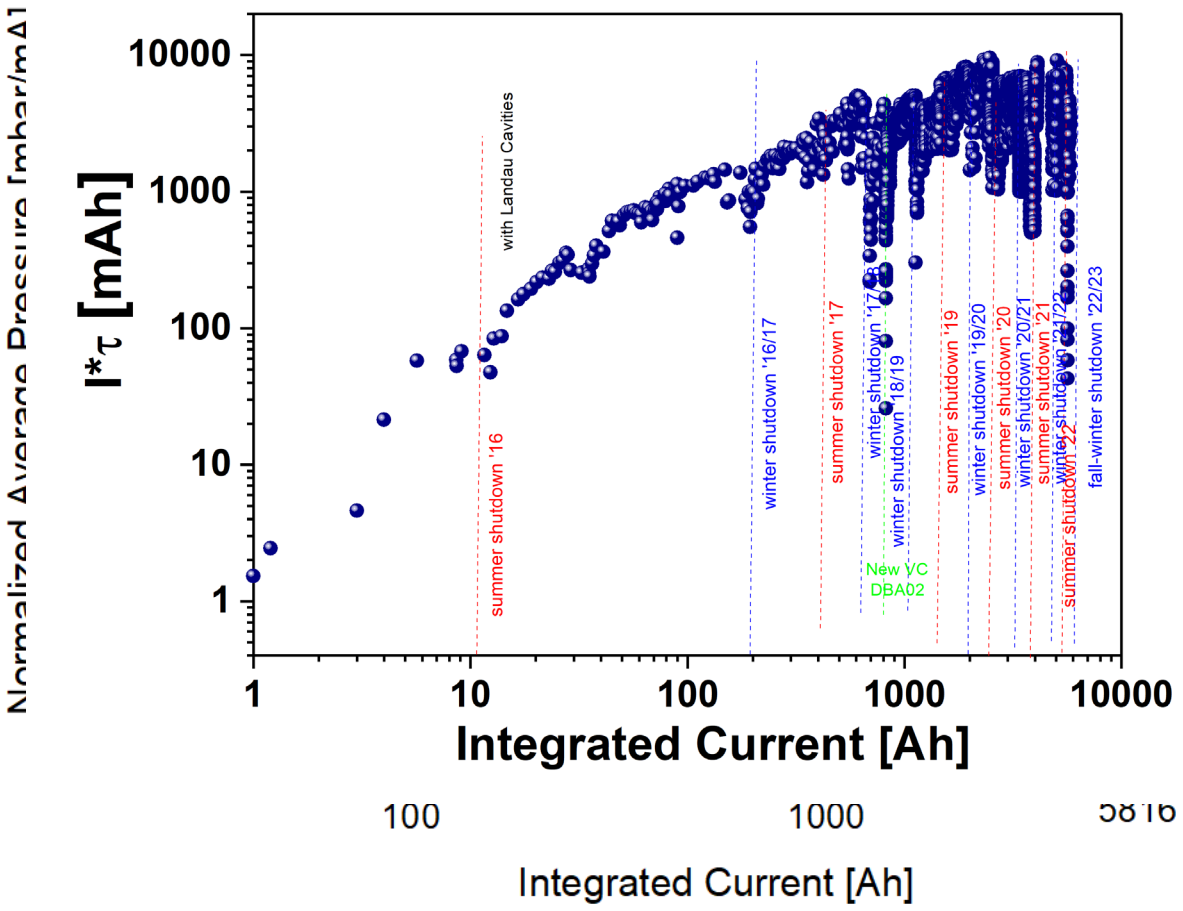




5 mm aperture is a critical place inside the vacuum chamber

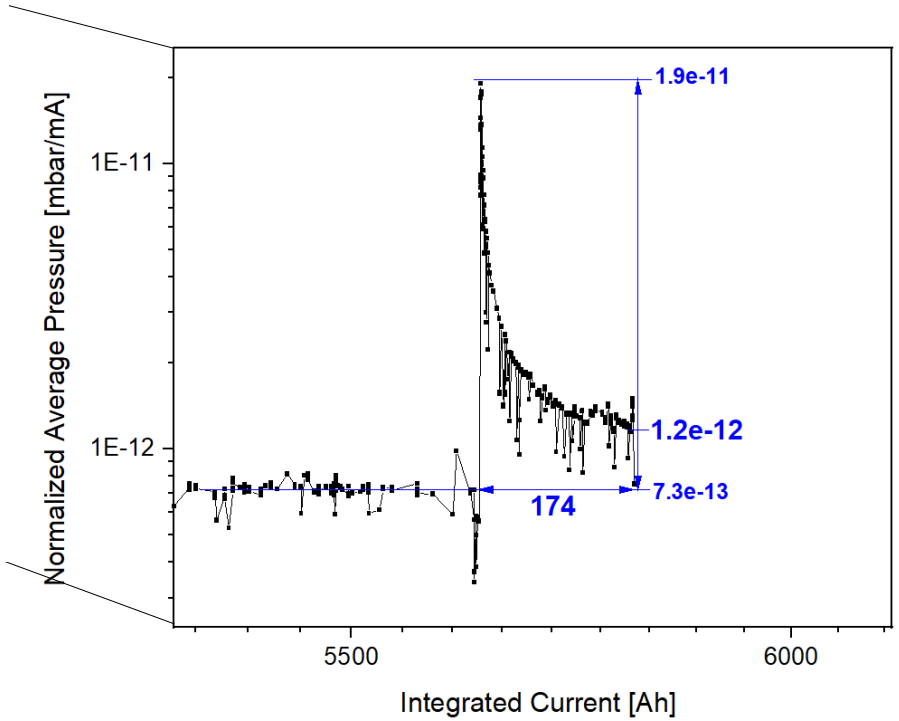
CONDITIONING OF THE STORAGE RING

Conditioning to get back to full operation with nominal current 2 weeks.



- Normalized average pressure measured by 24 sputter ion pumps from all band section (dipole vacuum chambers) for 200mA of beam current and 1.5GeV energy of electrons.

- Accumulated charge (integrated current) from the beginning of operation of the storage ring 5816 Ah.



CIRCULATOR

Arcs detected on the 2nd circulator

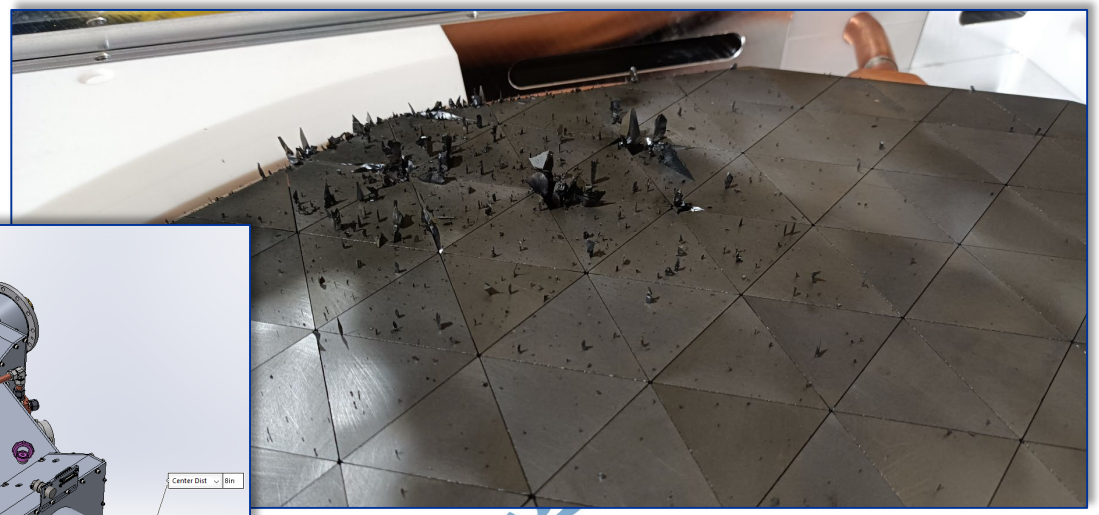
Damaged ferrites

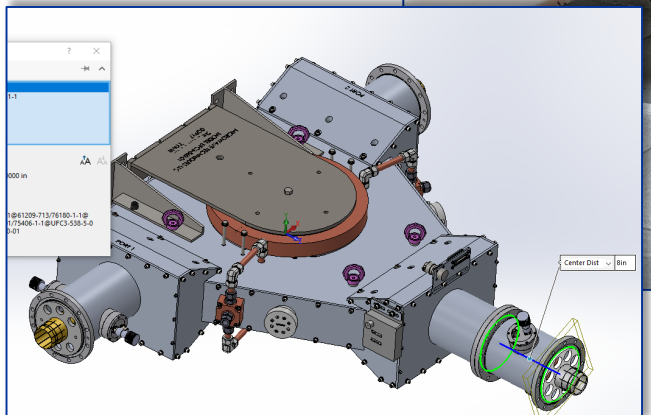
After clean-up a circulator works well

New circulator

M-A-C MICRO-ACTIV COMPONENTS
KRAWCZYK I WSPÓLNICY Spółka Jawna

- Parameters
  - Frequency: 99.93 .2 MHz
  - Average power: 120 KW (forward and reflected)
  - Insertion loss: f0: 0.2 dB
  - Bandwidth: 0.2 dB MAX
- Smaller
- 2 mounting possitions (horizontal/ vertical)
- New arc detecting system (MIS)
- Delivery: Jan-Feb 2023



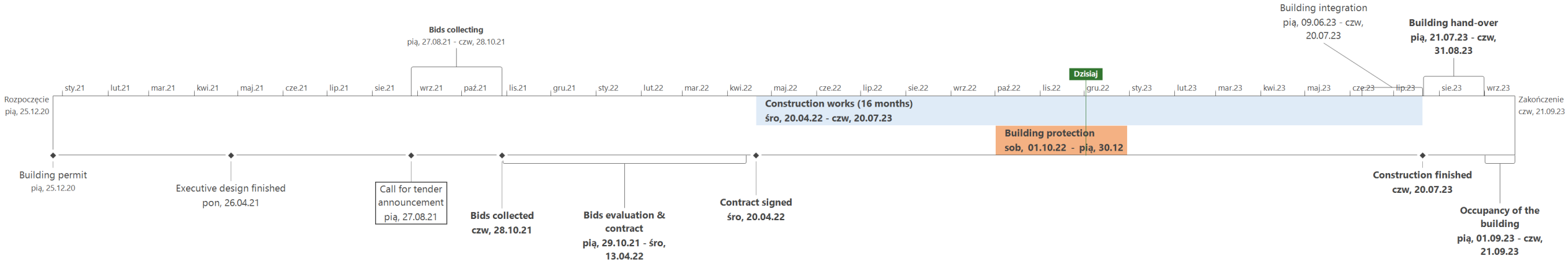


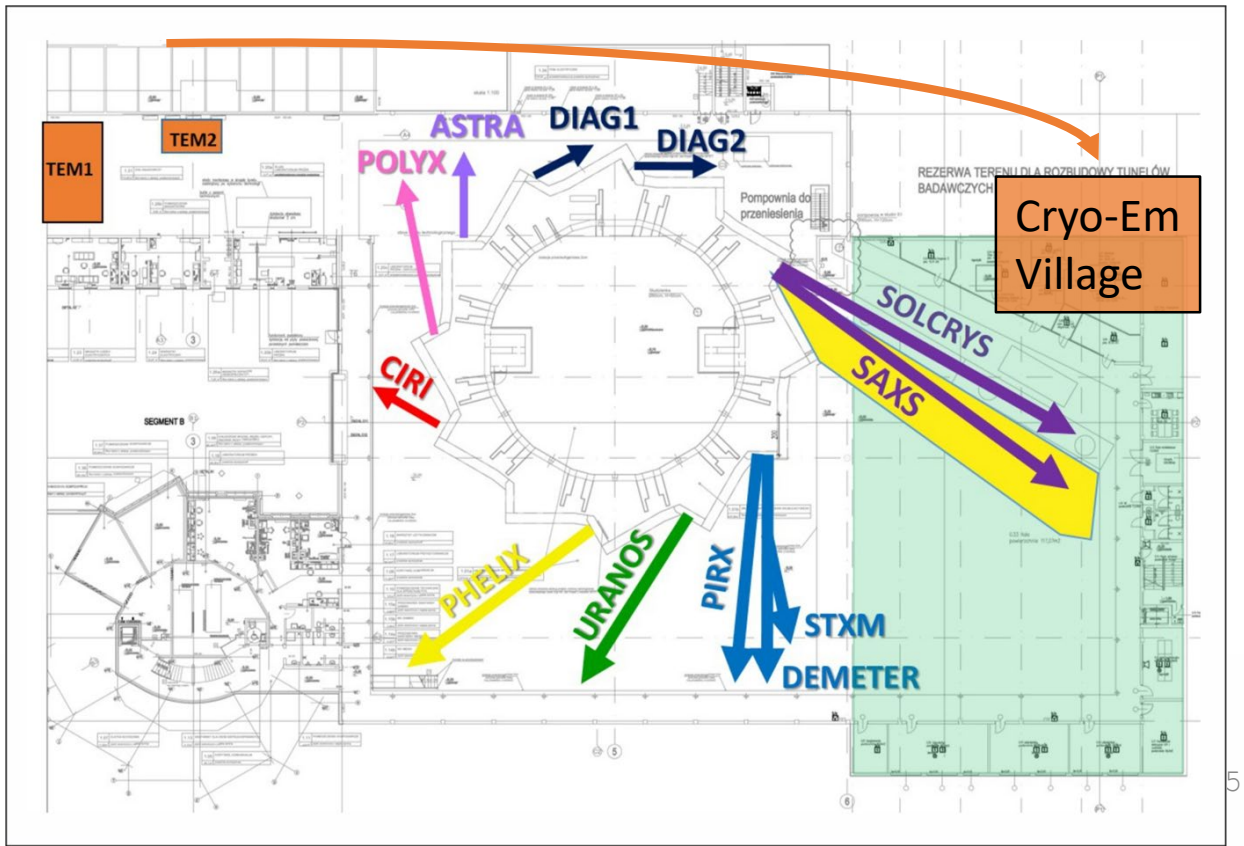
JAGIELLONIAN UNIVERSITY IN KRAKÓW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

SOLARIS DEVELOPMENT

SOLARIS EXPERIMENTAL HALL EXTENSION

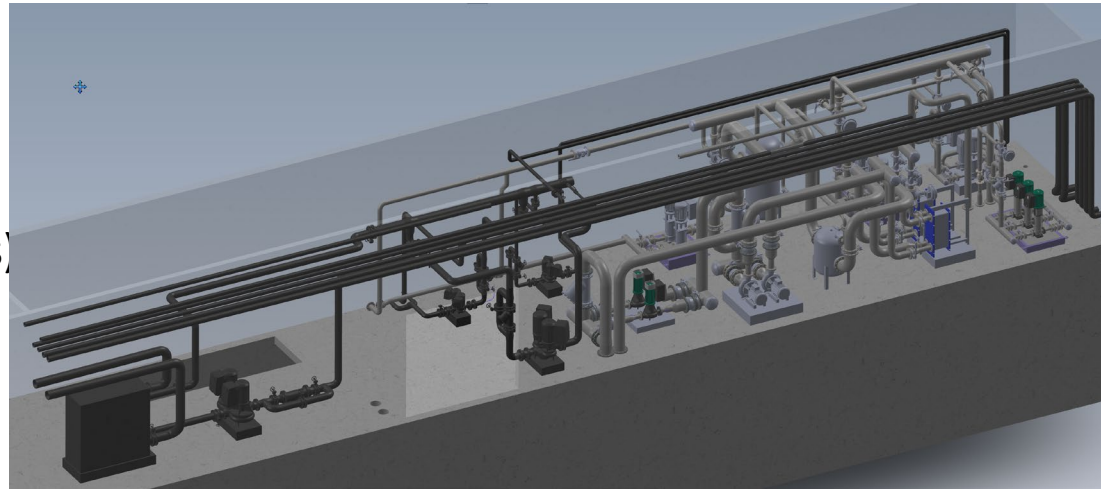




COOLING WATER UPGARDE

Main goals

- Improved temperature stability (±0.1°C)
- Redundancy of aggregates (possibility of "disabling" the unit)
- Buffer outside (possibility of adding aggregates)
- Cascade temperature control - 3-way valves (I-exchangers, II-circuits)
  - Proof of concept: 06/2020 -> (±0.05°C)
- Replacement of compensators
- Improvement of temperature regulation (new PLC system)



Other goals:

- Hydraulic clutch - pressure/flow stability
- Replacement of the EH+1.34 pipeline (DN40->DN50)
- Pipeline replacement Service Gallery (DN80->DN100) modernization of water systems, transmitter-circulator (V: 180 -> 360 l/min) → extension of the RF system
- Replacing/adding shut-off dampers in the engine room (lesson on "acid poisoning")
- Improving the ergonomics of operating devices in the engine room arrangement/placement of devices vs communication (supporting structure + slings) transport opening + hoist Active pH control
- Reduction of vibrations -addition of "inertial plates" under the pumps (+vibro-insulators) + slings with dampers, replacement of check valves from flap valves (vibration/wear) to spring ones
- Container outside - giving space for the Neutron Laboratory

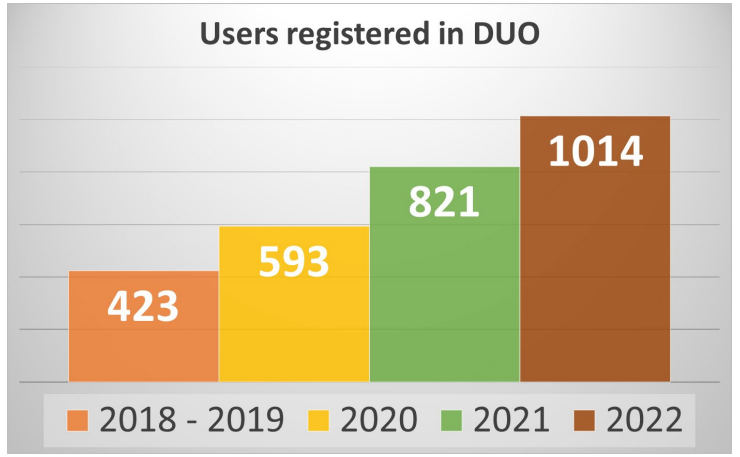
USERS' COMMUNITY DEVELOPMENT

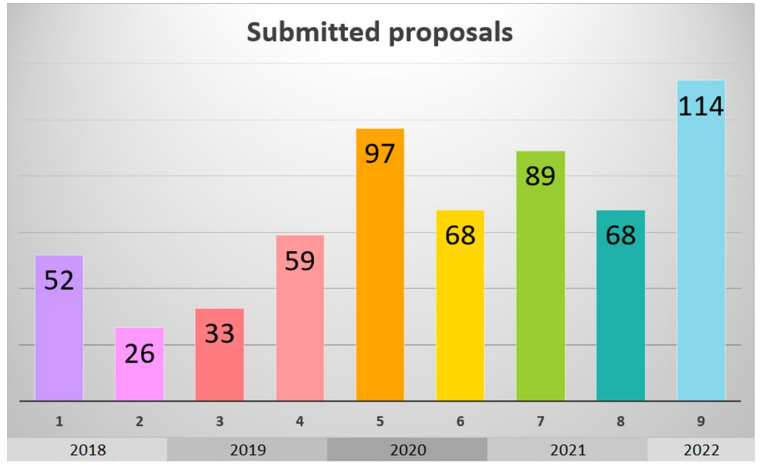
Number of users: 423 (2019) → **1000+ (2022)**

Access time applications: 92 (2019) → **157 (2021)**

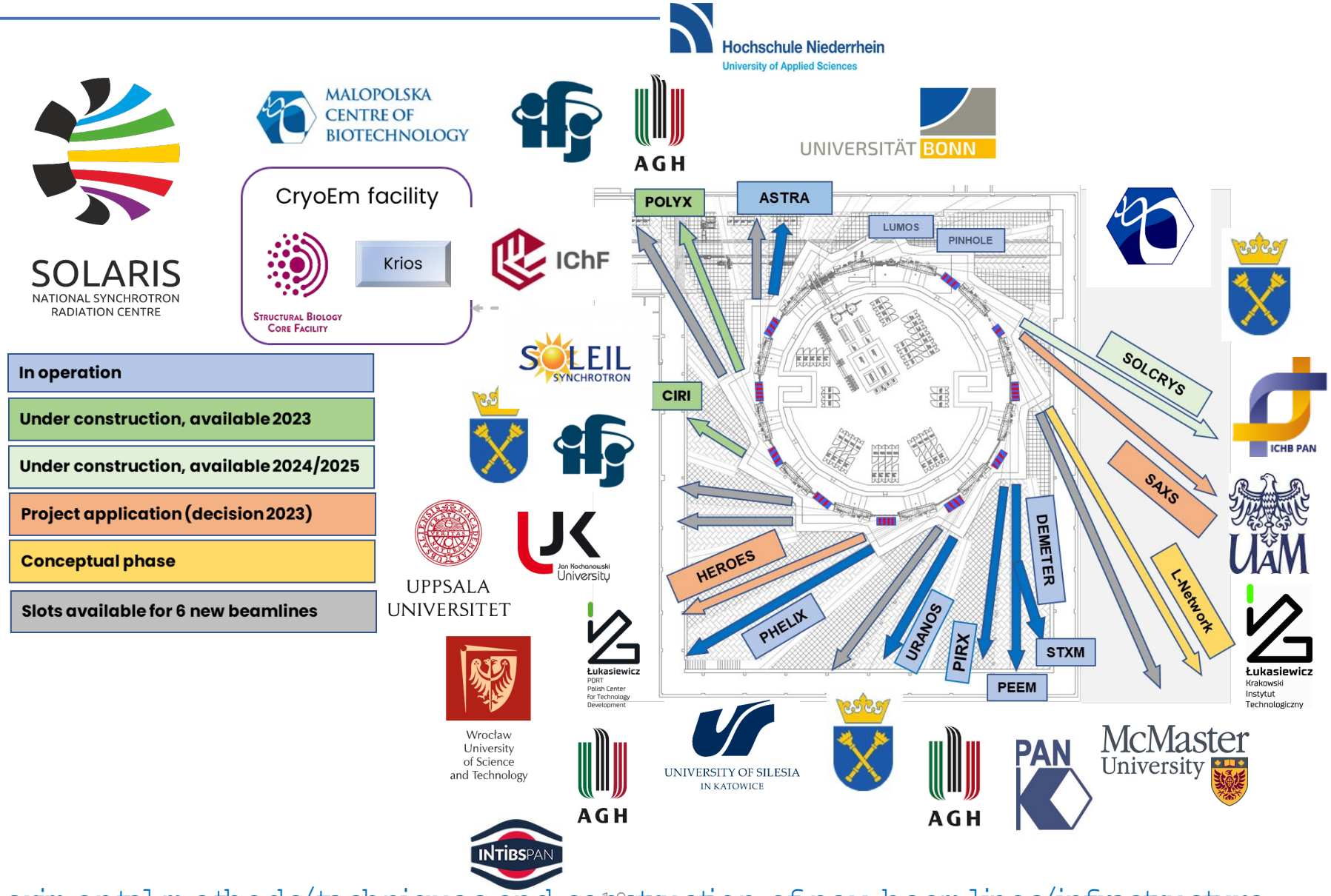
International users: 15% (2019) → **36% (2021)**

Accelerator avilability: 2530h/105days (2019) → **4654h/193days (2021)**





SOLARIS BEAMLINES DEVELOPMENT



Development of experimental methods/techniques and construction of new beamlines/infrastructure

NEW BEAMLINES DEVELOPMENT

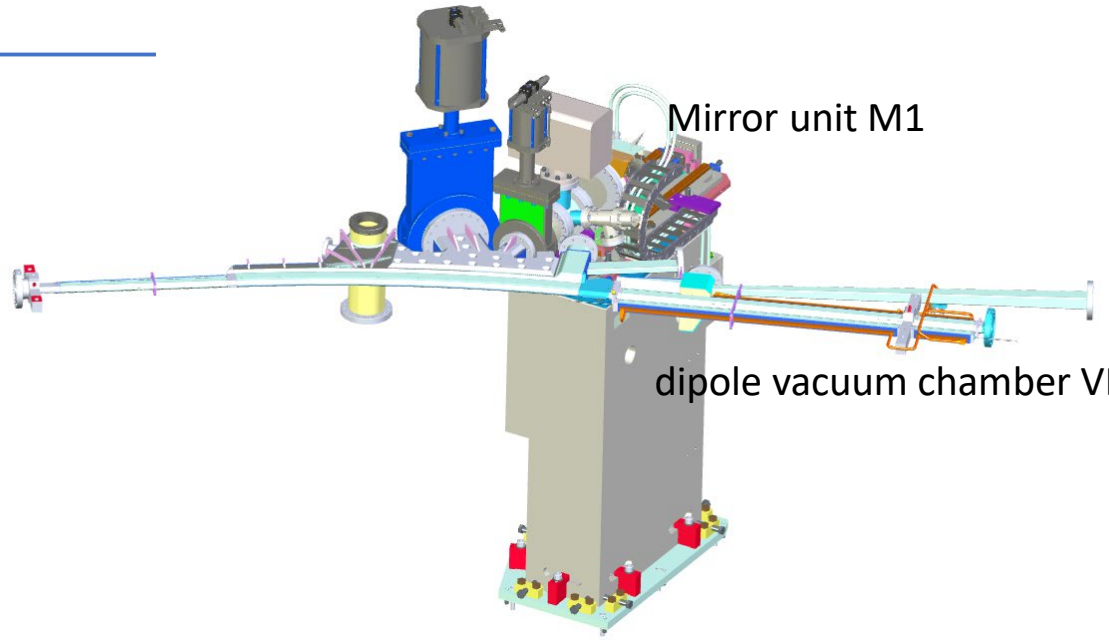
SOLAIR preparation for installation process

- The currently constructed Solaris Advanced IR beamline (CIRI) will allow radiation extraction in a very wide wavelength range (0.2 - 500 µm), including far (FIR) to near infrared (NIR).

- The extraction of infrared radiation from synchrotron radiation is done by using first flat mirror M1 located in the VK1m vacuum chamber where electron beam circulates. New dipole vacuum chamber VK1m was designed and now is at the manufacturing stage.

- Vacuum requirements regarding mirror M1 fulfilled during FAT (FMB) and SAT (SOLARIS)

- Vacuum chamber VK1m during manufacture stage up to end of 2022

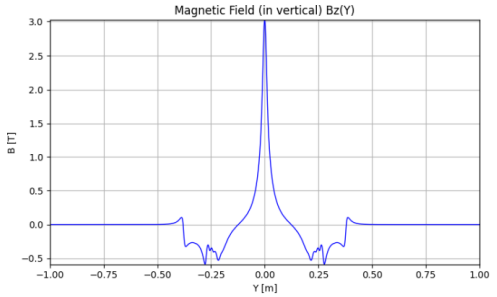


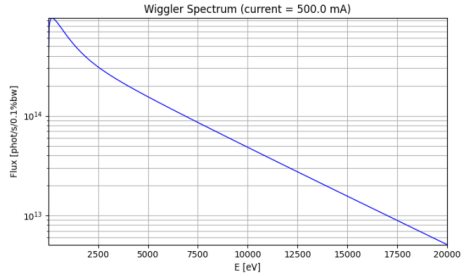
NEW BEAMLINES DEVELOPMENT

HARD X-RAY BEAMLINE

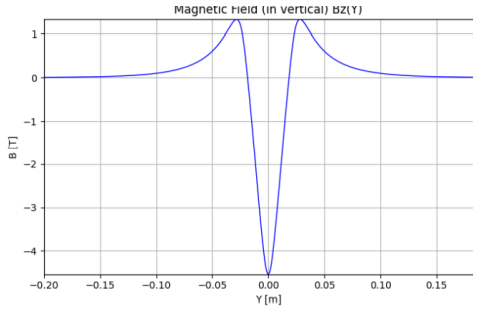
Problems and challenges

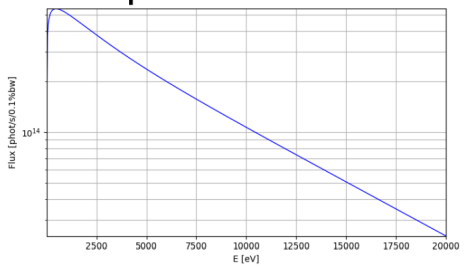
- Purchases of the superconducting wiggler from Budker (BINP)
  - Due to the geopolitical situation, the purchasing procedure has been stopped
  - New source of light for the SOLCRYS beamline is being searched
  - At the moment consideration of:
    - 3PW 3T permanent magnet similar as for BEATS project
    - 3PW 4.5 T superconducting wiggler
    - CLS BioXAS 2.1T, permanent magnet device - max field 2.1 T - λw = 150 mm - 11 periods - 1600 mm magnet length



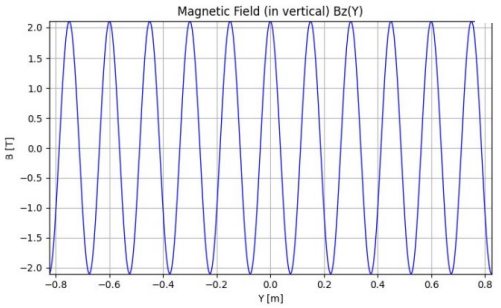


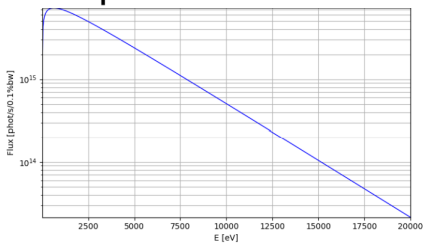
Total power 418 W





Total power 550 W





Total power 5140 W

- *MX beamline layout kept as in original design:*

  VCM 25 m, DCM 27 m, TFM 30 m, sample 45 m,

ORBIT CORRECTION IMPROVEMENT

1. Slow Orbit correction optimisation. The correction relaxation algorithm was applied and new Golden Orbit was set in June. The optimisation algorithm uses the correction response to the BPMs offset change.

Main benefits:

- ✓ Correctors power supplies current reduction from saturation region at 11 A below 5 A.
- ✓ Electric power reduction over 80% from: 603 W to 113 W, monthly 372 kWh less energy used.
- ✓ New orbit has no noticeable effect on parameters such as lifetime, chromaticity and dispersion.
- ✓ It was confirmed that there is no increase in ring thermocouples temperature, with new orbit we have 25 % drop in vertical emittance

2. Improvement of the orbit correction during the ramping – active correction.

3. Fast orbit feedback system development

- ✓ All hardware installations have been finished (24 correctors installed, connected to PS, and Liberas GDX modules).
- ✓ Hardware connections were verified and tested.
- ✓ First proof-of-concept measurements and test runs were performed.
- ✓ The core of the work focuses now on experimentally determining parameter values, control softwar development and solving problems as they arise.
- ✓ The machine studies time is shared with other new developments, but we expect to have first FOFB-enabled operations next year.

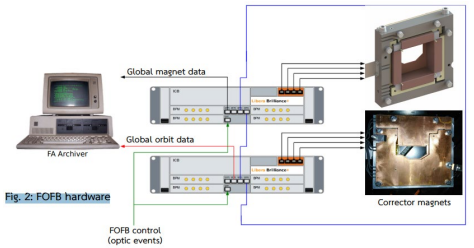
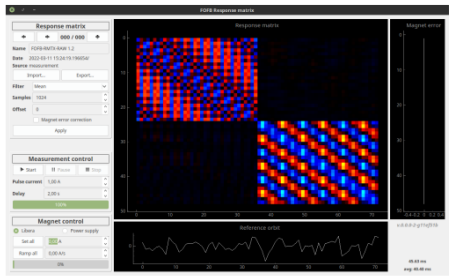
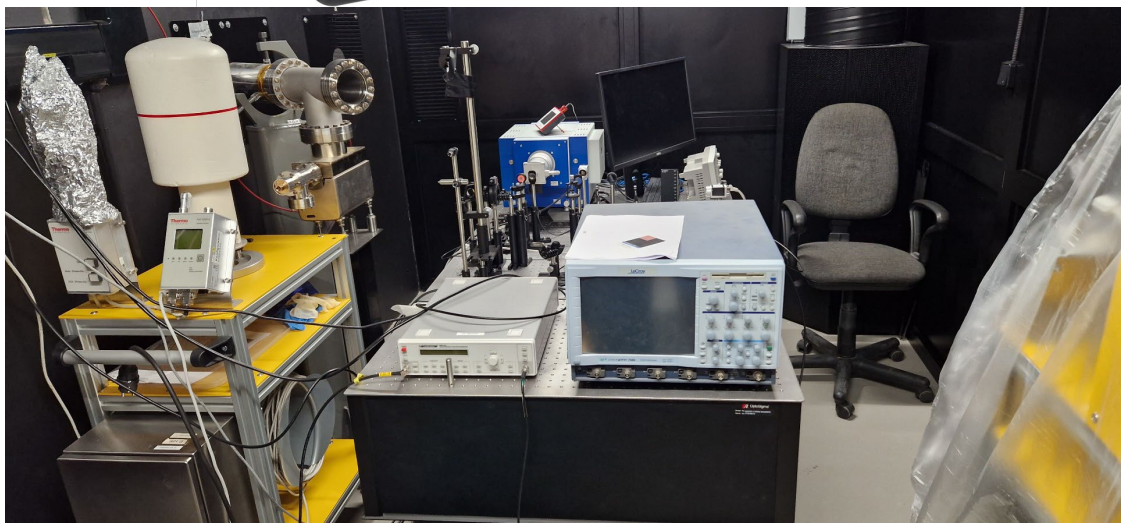


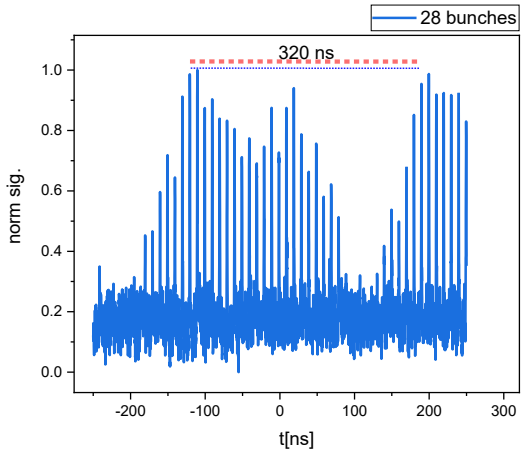
Fig. 2: FOFB hardware



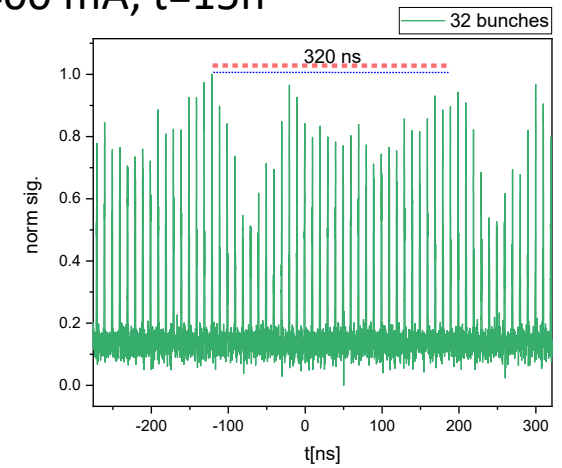
SINGLE BUNCH OPERATION DEVELOPMENT

The Filling pattern measured with fast photodiode at LUMOS beamline.

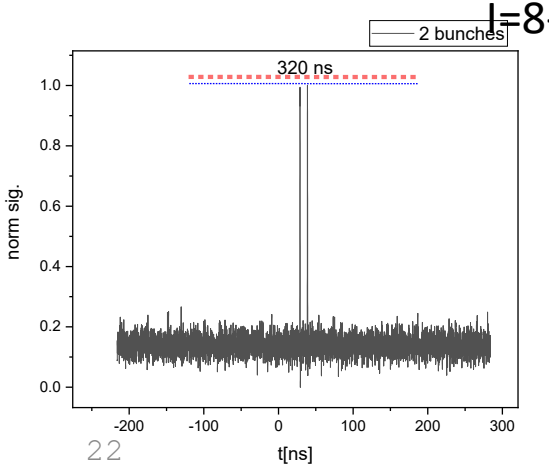


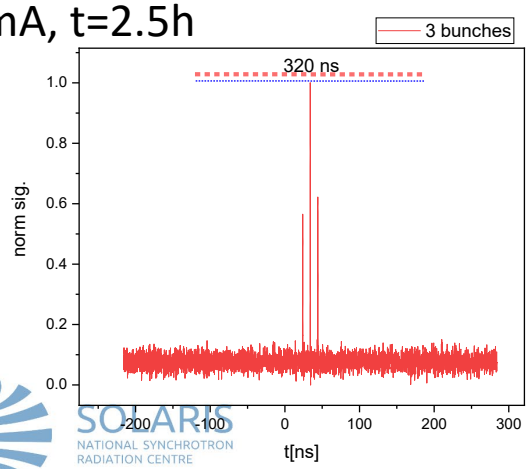


I=400 mA, t=15h



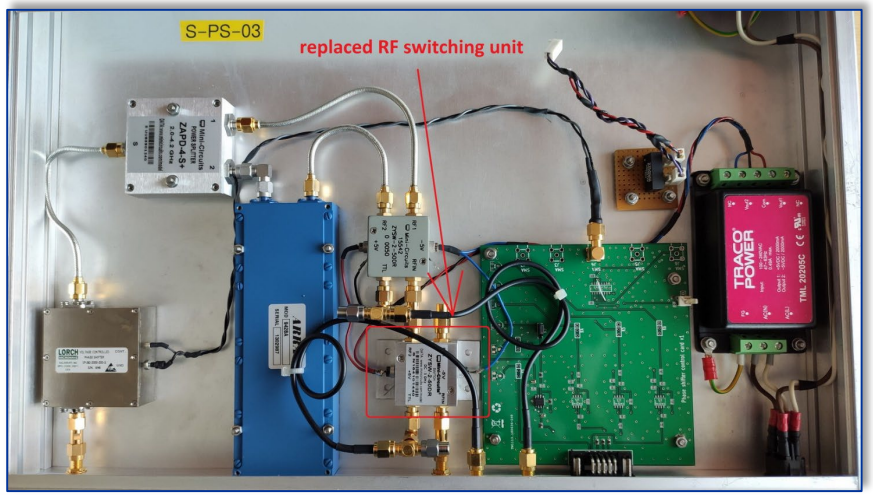
I=8-12 mA, t=2.5h

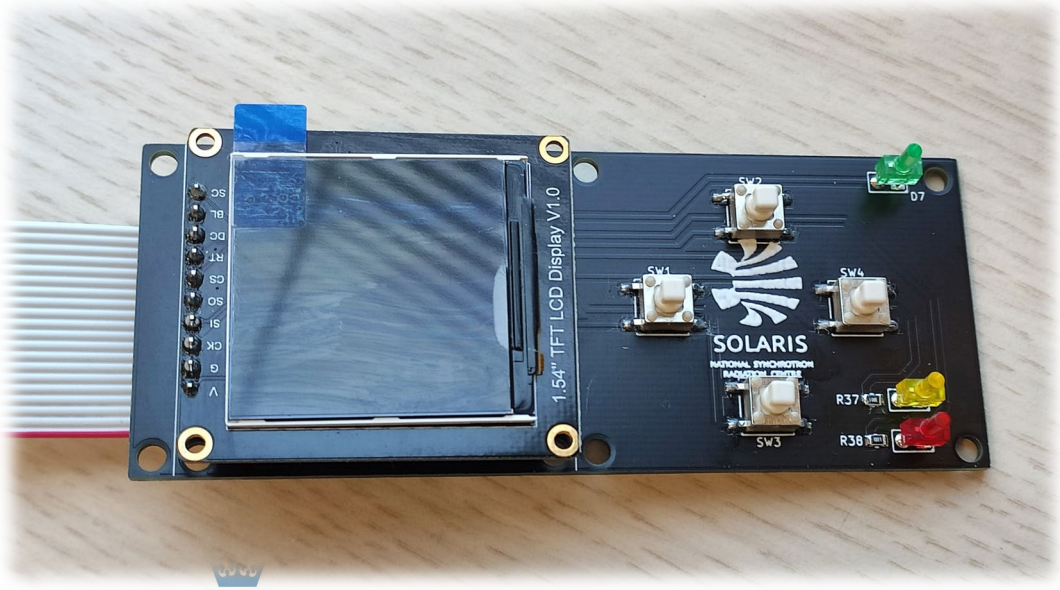


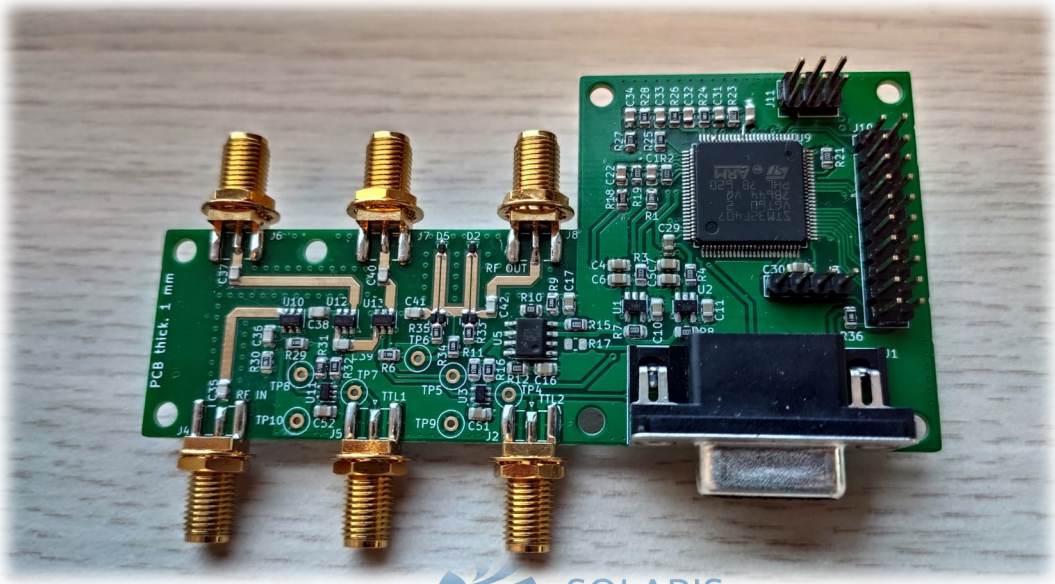


LINAC PHASE SHIFTER

- 10% less rf power behind SLED on the k03 section
- RF pulse instabilities detected (phase angle moving)
- Failed module Found and replace in the phase shifter
- RF phase shifting part integrated on custom made PCB
- Fast phase switching (<10ns) added - is required by SLED structures
- Removed mechanical and third party components from old design

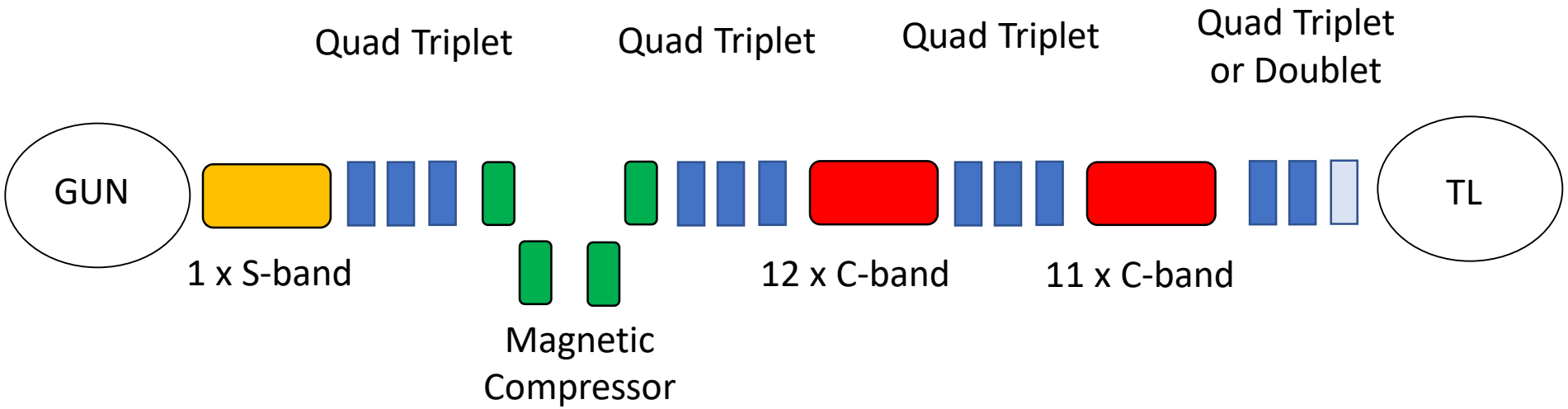






LINAC UPGRADE

Layout of the hybrid S-band/C-band LINAC with magnetic bunch compressor



Matching triplets is used to match the emittance into the Magnetic Compressor, the C-band LINAC, the TL
Linac design is done for the full energy injector and Short Pulse Facility
C-band LINAC 1.8 m long structures with 102 cells, 5.712 GHz, an average gradient 35.6 MV/m [1]
Ongoing work on optics optimisation, error studies,
Defining the RF, magnets, diagnostics, vacuum systems
Next step: works on RF distribution, mechanical design

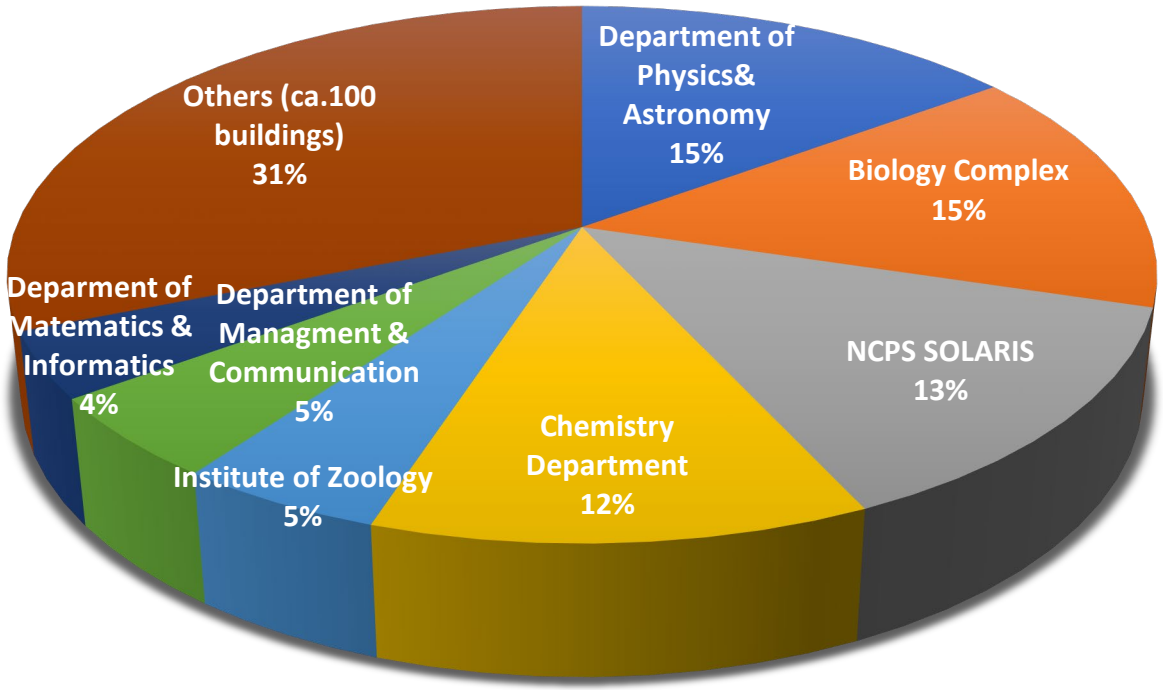
[1]Alesini, David, et al. "The damped C-band RF structures for the European ELI-NP proposal." Proceedings of IPAC2013, Shanghai, China (2013): 2726

SOLARIS ENERGY SAVING

ENERGY CONSUMPTION OVERVIEW

Annual energy consuption at Jagiellonian University

Total energy consumption for 2022 at JU 50 613 MWh/year



Energy consumpsion at SOLARIS (13%)

2 x 15 kV lines

6843 MWh-2021 total (488 183 EUR/Y)

~ 5641 MWh 2022 estimated ,(632 039 EUR/Y)

Peak power 1371 kW -19.08.2022 , constant ~1MW

Electricity consumption split	MWh/year	
Accelerators	**3 838.3**	**56.1 %**
Linac	306.7	4.5 %
Storage ring	3 531.6	51.6 %
Cooling , heating, air conditioning	**1 664**	**24.3%**
Offices	**448.7**	**6.6 %**
Lighting	**394.2**	**5.8 %**
Microscopes	**219**	**3.2 %**
Beamlines	**148.1**	**2.2 %**
Data centre	**131.4**	**1.9 %**
Total (2021)	**6 843**	

ENERGY SAVING

Actions implemented	En. saving
Heat pump improvement	74 MWh
Installation of LED lighting in the Linac (70% LED)	19 MWh
Installation of LED lighting in the office (50% LED)	8 MWh
Installation of LED lighting in the EXPH (100 % LED)	147 MWh
TOLAL	**248 MWh**

Proposed action	En. saving
Demi water improvement	547 MWh
LED lighting in whole building	16 MWh
Air conditioning EXP- Hall - inverters (15% less consumption)	13 MWh
PV 4x50 kWp	4x50 MWh
TOTAL	**776 MWh**

Cost:
In 2022 60 % increase of energy price with respect to 2021.
In 2023 it is expected 100% increase of energy price with respect to 2022

In 2023 in total 3.5 months shutdown is palnned (2 months –summer, 1.5 winter)
Moreover if the economy situation will change – further increase of electricity - we might be forced for further switch off – no decision was made so far.

SUMMARY

1. The main invasive works experimental hall extension building and cooling system upgrade has started in mid of 2022. The operation time was cut about 30 % with respect to last year.
2. The beam availability in 2022 was 94% with MTBF 116h and MTTR 8.5h.
3. New golden orbit was set improving the SOFB system.
4. Single bunch mode operation is being developed.
5. Design work on linac upgrade in ongoing.
6. The operation calendar for 2023 foresees 3.5 months of shutdown periods, and no other long shutdown is planned yet. However we have to be prepared for shutdown extension due to economical crisis.

Thank you for your attention!